2022 - 2025 STRATEGIC PLAN

INSTITUTO DE ASTROFISICA DE CANARIAS · IAC ·

MARCH 2021

EXECUTIVE SUMMARY

The IAC is the largest astrophysics research centre in Spain. Its vision for 2022-2025 will focus on consolidating international leadership in Astrophysics and Space Sciences by delivering cutting edge scientific and technological outcomes, strengthening the astronomical reserve of the Observatorios de Canarias (OOCC), and promoting the transfer of knowledge between the scientific community and society. The following main goals will contribute to this purpose:

I. RESEARCH EXCELLENCE AND TECHNOLOGICAL DEVELOPMENT. The Strategic Plan involves exploration and discovery using major world-class facilities, developing further physical insight, advanced modelling and innovation in technologies/techniques for ground/space observatories, and the generation of new knowledge in key areas of astrophysics with impact in fundamental physics.

The IAC scientific program will address problems on: very high energy phenomena in the Big Bang and around black holes; the genesis of cosmic and gamma-rays; formation and evolution of galaxies; including the Milky Way and the Local Group; the life cycles of stars; physics under strong gravity fields, the physics of magnetic fields in the Sun; and the detection and characterization of Earth-like planets in nearby stars. The IAC will use and develop a large variety of cutting edge ground/space facilities and attract talented young/senior researchers to promote advances and breakthroughs in observational astronomy, physical modelling, computer simulation and technology.

To accomplish this, the IAC will continue developing advanced telescopes (CTA, EST, NRT, ELF) and instrumentation for major ground-based observatories (e.g. GTC, ELT, WHT, GREGOR and TMT) and space observatories (e.g. EUCLID, PLATO, ARIEL). Over the next four years, technological activities will focus on high spectral resolution (HIRES, HARPS3, NIRPS), high spatial resolution (e.g. GTCAO/LGS, EST/AO), optical and infrared 3D spectroscopy (e.g. HARMONI, FRIDA, MIRADAS, WEAVE) and microwave instrumentation (e.g. QUIJOTE, TMS). Flagship projects for IACTEC, the new IAC technology initiative, are the Centre for Advanced Optical Systems (CSOA) and the Laboratory for Microsatellite Payloads and Optical Communications.

II. INTERNATIONAL DIMENSION, promoting a sustainable framework of international collaborations with the top-class research centres worldwide. International collaboration is in fact one of the defining characteristics and strengths of the IAC. The interaction with world-leading institutions and scientists stimulates top-quality research. The IAC is involved in the most relevant international consortia to address scientific challenges and the development of advanced telescopes and astronomical instrumentation.

III. ADVANCED TRAINING AND SOCIAL COMMITMENT. Based on a long-term partnership with University of La Laguna, a very intense training program for graduate students is proposed, which would lead to at least 50 new PhDs being defended over the next four years. IAC aims to hire 25-30 post-docs and 10 engineers every year (typically with of 2- or 3-year contracts) and will continue the annual organisation of the "Canary Islands Winter School of Astrophysics". Moreover, the IAC will foster its *SOCIAL COMMITMENT* by (1) enabling the best scientific and technological value for its research infrastructures and facilities; (2) promoting dissemination of science and public awareness; and (3) exploiting its technological capabilities in terms of socio-economic development; and (4) providing high-level training through vocational internships on communication, general administration, project management and technical training, among others.

The IAC faces outstanding opportunities: research infrastructures that will be installed in its Observatories; instrumentation projects for current and future telescopes, etc. Taking advantage of these opportunities requires strong and timely political and economic support, increased flexibility in public procedures, a significant increase of our capacity to recruit the best specialists from anywhere, and a higher number of scientific leaders - among other key aspects. Furthermore, IAC aims to develop its active technology transfer program in close collaboration with industry to deliver new robotic telescopes, payloads for small satellites and applications in biomedicine, enabling a broader socio-economic impact.

A budgetary plan is proposed to obtain during the first two years a level of stable internal funding amounting to 20 M€ p.a. from the Public Administration, to be sustained over the subsequent 2 years. External funding obtained via competitive calls is currently about 4 M€ p.a. for the IACs Research and Technology Programmes and 10 M€ for the Large Institutional Projects (CTA, EST, NRT, TMT, IACTEC), respectively. The present plan aims to achieve an average level of external funding of order 22 M€ p.a. for the period 2022-2025.

As regards the evolution of the IAC's Human resources, in 2020 the IAC staff numbers reaches 433 people (including ULL & CSIC staff working at the IAC premises). Around 200 positions are dedicated to research (permanent researchers, post-docs and PhD students), around 120 positions are high level engineers (permanent and temporary), and the rest provide technical and administrative support. A proposal is made for the next four years to incorporate 12 new permanent positions for research and to increase the number of permanent (9) and temporary (13) engineering contracts to accomplish the development of new instruments, large telescopes (e,g. CTA, EST, NRT) and new technology programs (IACTEC). In addition, 8 new administrative and technician positions are also planned.

To successfully accomplish the present Strategic Plan, there will be a strong collaboration between the IAC Divisions (Research, Instrumentation and Graduate Studies) and the General Administration, which is responsible for the financial, economic, administrative, operational and budgetary management.

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1. INSTITUTO DE ASTROFÍSICA DE CANARIAS

1.1. Mission, vision and objectives

The Instituto de Astrofísica de Canarias (IAC) is a public research Consortium formed by the General Administration of the Spanish State (represented by the Ministry of Science and Innovation), the Canary Islands Regional Government, the University of La Laguna and the Spanish National Research Council (CSIC)

Mission

To perform excellent research and technological developments in astrophysics, securing the appropriate training of graduate students, young researchers and engineers, promoting outreach and technology transfer in many different areas and fostering a fruitful and stable environment of international collaboration.

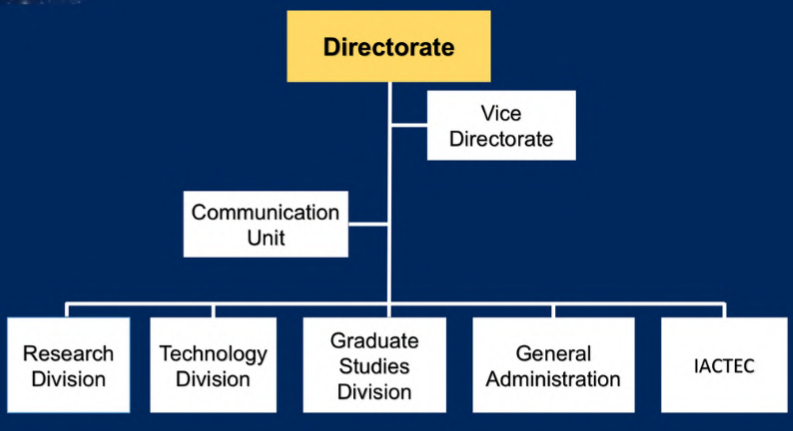
Vision

International leadership in Astrophysics and Space Sciences, by delivering excellent scientific and technological outcomes, strengthening the "astronomical reserve" of the Observatorios de Canarias (OOCC), and promoting the transfer of knowledge between scientific communities and society.

Objectives

The IAC's main objectives, according to its statutes, are:

- to conduct and promote astrophysical research as well as to develop and transfer technology;
- to disseminate astronomical knowledge, collaborating in university teaching in the area of astronomy and training researchers and engineers in scientific and technical fields related to Astrophysics;
- to manage the centres, observatories and astronomical facilities already existing, as well as those to be built or assigned, and other related facilities,
- to promote relations with the national and international scientific communities



The IAC is governed by a Board (Consejo Rector) that is Chaired by the Minister of Science and Innovation and made up by representatives of the national and regional bodies which constitute the IAC.

The Director of the IAC reports to the Board, and is assisted by a Management Committee formed by the Vice Director, the IAC's General Manager and the Heads of the Research, Graduate Studies and Technology Divisions.

2. DESCRIPTION AND ANALYSIS OF THE PRESENT SITUATION

2.1. Overview

The IAC consists of its main headquarters in La Laguna in Tenerife, a sea-level site in La Palma, the two international observatories in Tenerife and La Palma and a new technology HQs (IACTEC) in La Laguna. In 2011 and subsequently in 2016 and 2020, the IAC was designated as Severo Ochoa Centre of Excellence by the Spanish government.

The IAC hosts and operates several Spanish Facilities for Science and Technology (ICTS, Instalaciones Científicas y Tecnológicas Singulares):

1. The Observatorios de Canarias (OOCC) on Tenerife and La Palma islands, where more than 40 telescopes and telescopic installations are run by institutions from a large number of countries. The IAC owns, and runs with other partners the 4.2m William Herschel Telescope (WHT) and the 2.5m Isaac Newton Telescope(INT), and a number of smaller telescopes (1.5 m TCS, 1m JKT, IAC80, QUIJOTE).
2. The 10.4 m GTC in La Palma, another ICTS is the largest optical telescope in the world, developed under the auspices of IAC and the forward-looking approach of the Research Division. Under the Law of Science, the GTC is a Spanish Scientific Infrastructure to be attached to the IAC.
3. A node of the National Supercomputer Centre, the third ICTS, is also hosted by the IAC.

There is a well-consolidated Research Division with (~65) permanent staff, (~70) research fellows, postdocs and support staff. IAC Postgraduate students (~55) do their research within the Research Division but are formally part of the IACs Graduate Studies Division and the Astronomy Department of the University of La Laguna. Researchers work on six major scientific areas: Solar Physics; Exoplanets and Solar System; Physics of the Stars and Interstellar Medium; Milky Way and the Local Group of galaxies; Formation and Evolution of Galaxies; and High Energy Astrophysics and Cosmology. IAC researchers are routinely awarded access to major astronomical facilities in the world (VLT, HST, GTC) and obtain competitive funding to carry out research and develop state of the art instrumentation for ground and space based telescopes. A significant fraction (>40%) of the IAC budget is obtained from competitive funding sources.

The IAC is well integrated in the international community, participating in the majority of the main astrophysical projects and consortia, as well as in the corresponding forums on RTD policies, in close relationship with national and international funding agencies and public bodies. Within the Canary Islands, the IAC enjoy widespread public and political support. In fact, astrophysics has been one of the main top priorities identified by the Canary Islands Research and Innovation Strategy for Smart Specialization (RIS3). The current scientific production, of more than one paper per day published in international peer reviewed journals with high impact factor, matches the production of other world-leading institutes of similar sizes, and often with higher funding level.

2.1.1 Human Resources

The number of persons directly employed by the IAC for research activities, technical and administrative support was 406 in 2020. Including the staff from the University of La Laguna (24) and from the Spanish National Research Council (CSIC, 3), all working at the IAC HQ, the total number of IAC members was 433 in 2020. The following diagram shows these figures for researchers, technical and administrative staff.

Technical staff is divided into engineers and workshop technicians associated to the Instrumentation Division, the IT & services and other units (IACTEC, Observatories, etc).

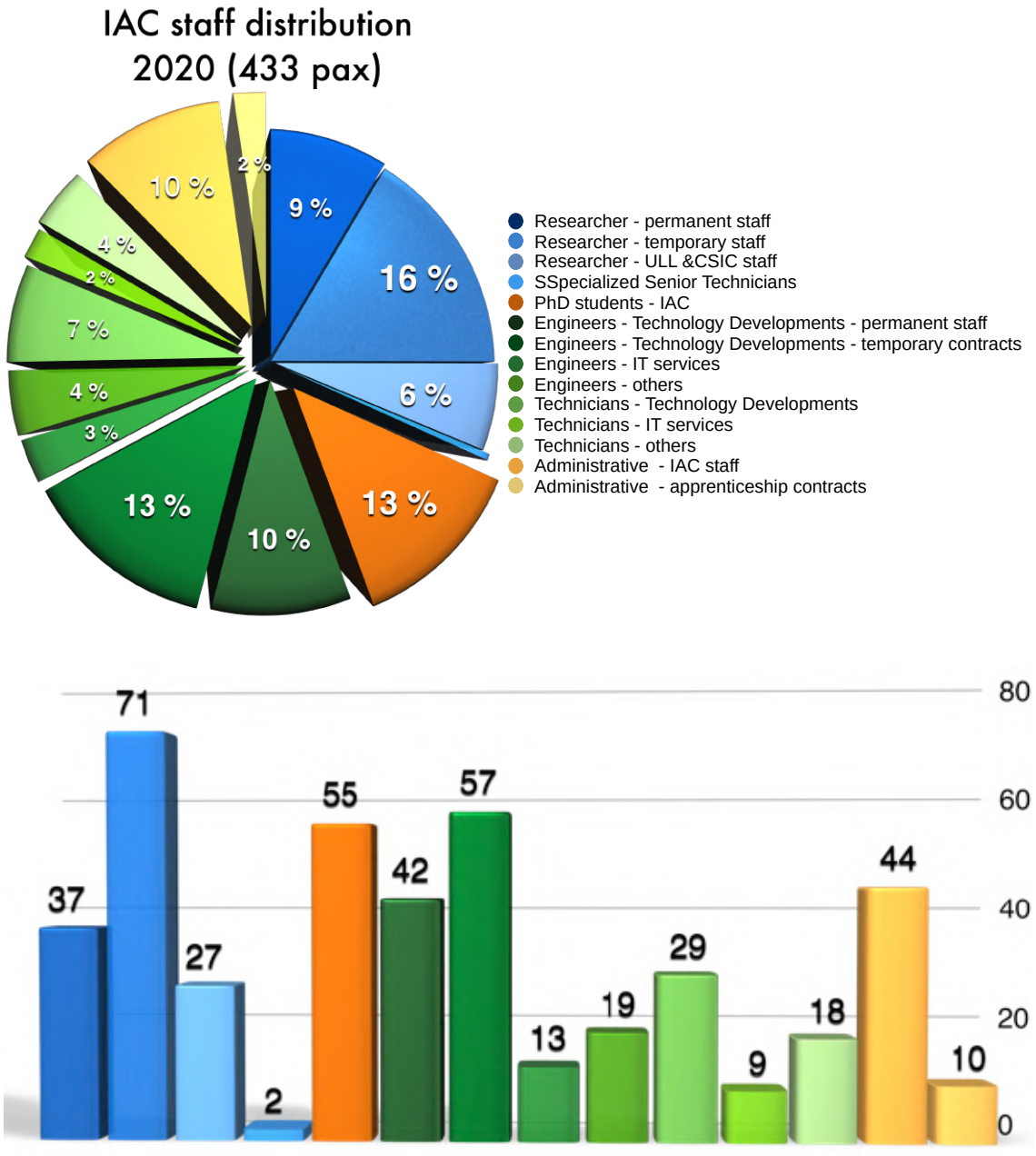


Figure 2.1

Evolution of IAC's Human Resources 2017 – 2020

Group	Profile		2017			2018			2019			2020		
			Male	Female	**Total**	Male	Female	**Total**	Male	Female	*Total*	Male	Female	**Total**
Researchers	Researcher - permanent staff		28	5	**33**	32	5	**37**	32	5	**37**	31	6	**37**
	Researcher - temporary staff		47	23	**70**	46	23	**69**	49	20	**69**	55	16	**71**
	Researcher - ULL &CSIC staff		22	2	**24**	21	3	**24**	22	3	**25**	23	4	**27**
	Specialised Technical staff		0	0	**0**	0	0	**0**	0	0	**0**	1	1	**2**
PhD students	PhD students - IAC		37	22	**59**	30	23	**53**	33	21	**54**	31	24	**55**
Technical staff	Engineers - Technology Developments - permanent staff	Engineers	25	8	**33**	26	8	**34**	25	8	**33**	30	12	**42**
	Engineers - Technology Developments - temporary contracts	Engineers	28	8	**36**	36	10	**46**	44	12	**56**	46	11	**57**
	Engineers - IT services	Engineers	11	2	**13**	11	2	**13**	10	3	**13**	10	3	**13**
	Engineers - others	Engineers	4	11	**15**	6	11	**17**	7	11	**18**	8	11	**19**
	Technicians - Technology Developments	Technicians	29	3	**32**	28	4	**32**	31	1	**32**	26	3	**29**
	Technicians - IT services	Technicians	7	2	**9**	7	2	**9**	7	2	**9**	7	2	**9**
	Technicians - others	Technicians	16	0	**16**	16	0	**16**	18	0	**18**	18	0	**18**
Administration	Administrative - IAC staff		15	30	**45**	15	30	**45**	14	27	**41**	15	29	**44**
	Administrative - IAC apprenticeship contracts		1	3	**4**	1	7	**8**	1	13	**14**	0	10	**10**
	TOTAL		**270**	**119**	**389**	**275**	**128**	**403**	**293**	**126**	**419**	**301**	**132**	**433**

The percentage of temporary contracts vs. permanent positions at the IAC was basically flat during the last years, from 48% in 2015 up to 51% in 2020. These temporary contracts are usually offered under the framework of RTD projects supported by external funds, with a duration from 2 to 4 years and are mainly awarded to postdocs and/or engineers.

IAC staff: Temporary .vs. permanent positions. 2015 - 2020

Type of recruitment	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
% temporary pos.	*48%*	*48%*	*50%*	*50%*	*54%*	*51%*

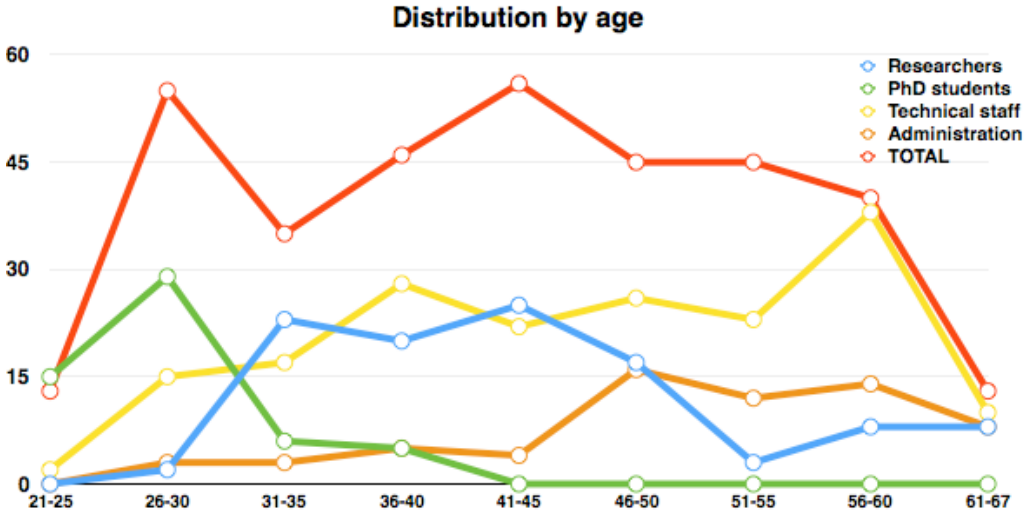
In accordance with standards commonly accepted the ratio at the IAC among researchers, technical and management staff should be situated in the range of 1:2:0,5. Currently, this ratio is 1:1.4:0.3.

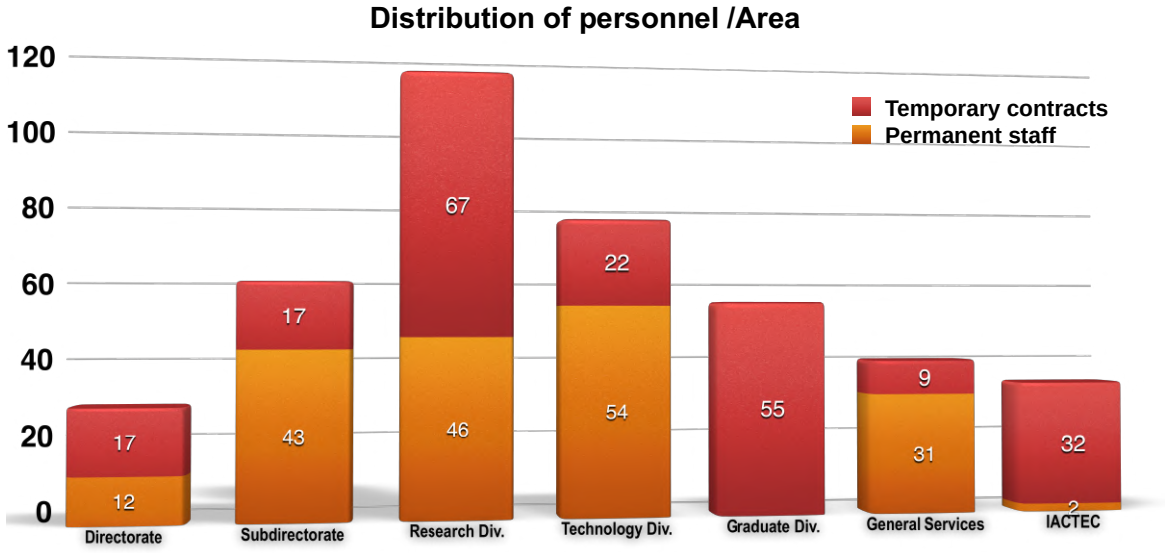
This ratio has slightly improved throughout the last years for the case of technical staff, but unchanged in the case of management staff. Some specific actions to change this situation for the coming years will be proposed in the Strategic Plan.

Ratio vs. researchers	**2016**	**2017**	**2018**	**2019**	**2020**
technical staff	1,23	1,21	1,28	1,37	1,36
management staff	0,35	0,35	0,35	0,31	0,32

Concerning gender issues, distribution by age, and distribution of IAC staff (directly under IAC contracts) per category, the current situation at the centre is the following (ULL & CSIC staff is not included):

Gender (%)		
Category	**Men (%)**	**Female (%)**
Researchers	79,1	20,9
PhD students	56,4	43,6
Technical staff	77,5	22,5
Administration	27,8	72,2
Total	**68,5**	**31,5**


Distribution by age
60
45
30
15
0
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-67
Researchers
PhD students
Technical staff
Administration
TOTAL


Distribution of personnel /Area
120
100
80
60
40
20
0
Temporary contracts
Permanent staff
17
12
17
43
67
46
22
54
55
9
31
32
2
Directorate
Subdirectorate
Research Div.
Technology Div.
Graduate Div.
General Services
IACTEC

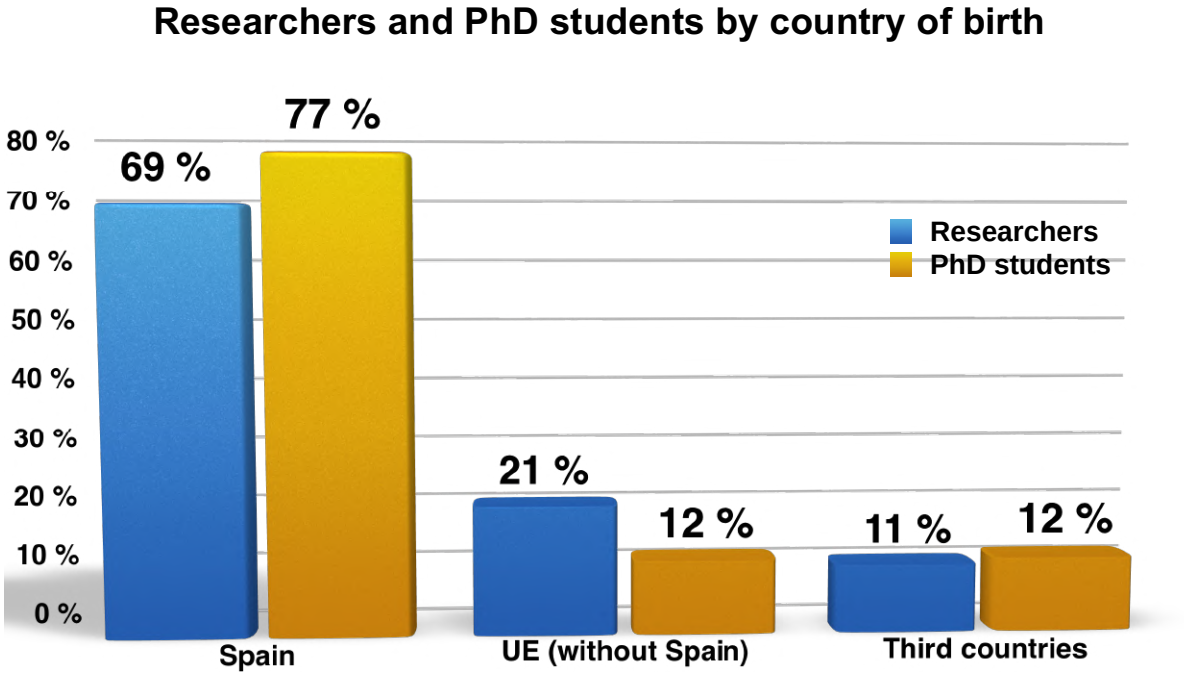
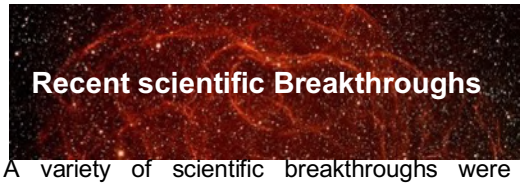

Researchers and PhD students by country of birth
80 %
70 %
60 %
50 %
40 %
30 %
20 %
10 %
0 %
69 %
77 %
21 %
12 %
11 %
12 %
Researchers
PhD students
Spain
UE (without Spain)
Third countries

Figure 2.2

2.1.2 Research Division

IAC Researchers represent approximately 25% of the Spanish community. At present, there are 66 permanent staff, 75 research fellows and postdocs and 55 Postgraduate (PhD) students working on six major scientific areas: Solar Physics; Exoplanets and Solar System; Physics of the Stars and Interstellar Medium; Milky Way and the Local Group, Formation and Evolution of Galaxies; and High Energy Astrophysics and Cosmology.

The Research and Instrumentation programme at the IAC is jointly undertaken by the Research and the Instrumentation Divisions, although the majority of IAC personnel carrying out research activities are members of the Research Division, along with some support personnel. This Division is coordinated by the Head of Research (Coordinador de Investigación), an IAC staff member appointed for a period of 2 to 4 years who forms part of the IAC's directorate (Management Committee or Comité de Dirección).



A variety of scientific breakthroughs were achieved by IAC researchers during the last few years. We highlight: (a) the complete mapping of the sun's magnetic field from the photosphere to the base of the corona, (b) the characterization of Earth-sized planets, (c) outstanding advances in stellar abundances that challenge our understanding of stellar nucleosynthesis, (d) the first detection of Near-IR winds around a stellar black hole, (e) the detailed reconstruction of the Milky Way star formation history, (f) the dark matter content around ultra-diffuse galaxies, (g) unveiling the origin of cosmic rays and the follow-up of gravitational wave events. IAC researchers also participated in the new release of SDSS-IV data on the 3D structure of galaxies in the nearby Universe.

The Research programme is implemented through a **coherent set of activities** with the common goal of excellence at the international level, primarily using observational techniques, exploiting not just the facilities at the IAC observatories but also, and increasingly so, those available to us in the context of the international collaborations which Spain has formed, in particular with the European Southern Observatory and the European Space Agency. In this regard, IAC researchers are routinely awarded access to major astronomical facilities in the world (VLT, HST, GTC) and obtain competitive funding to carry out research and develop state of the art instrumentation for ground and space based telescopes.

Main research performance indicators

The last 10 years of research activity has generated a positive trend in production of research articles, strongly correlated with the articles published in Q1 journals (see figure below).

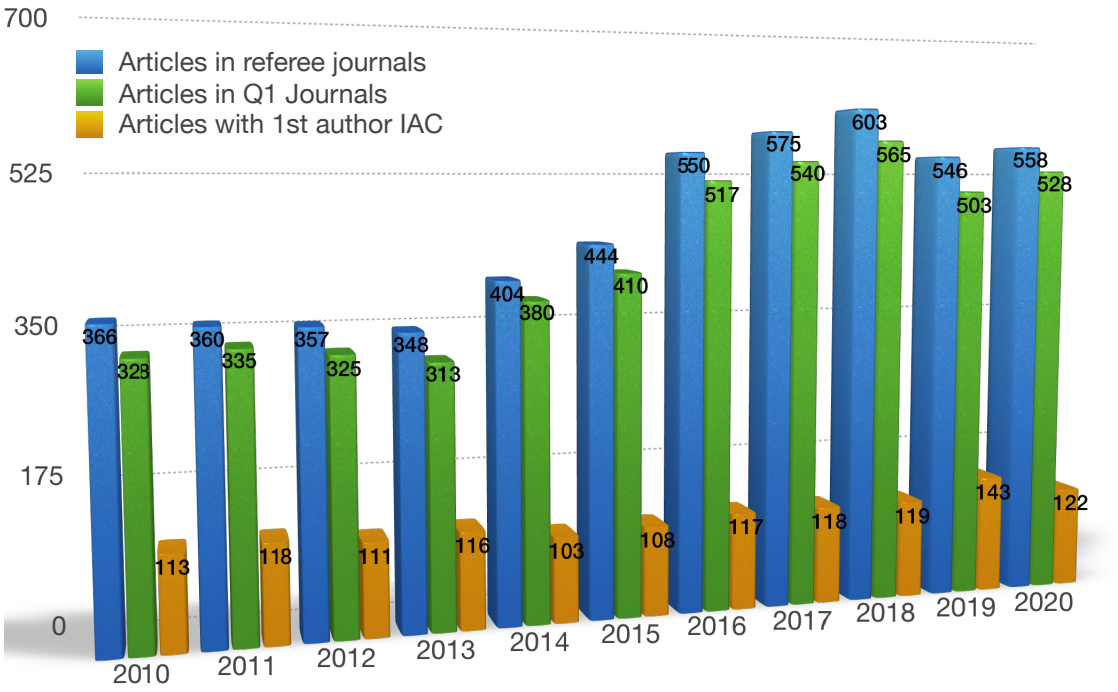


Figure 2.3: Number of articles per year published in total (blue), in the top rank (Q1) Journals in Astrophysics (green), and total number of papers led by IAC staff (yellow). Source: Journal Citation Reports (JCR)

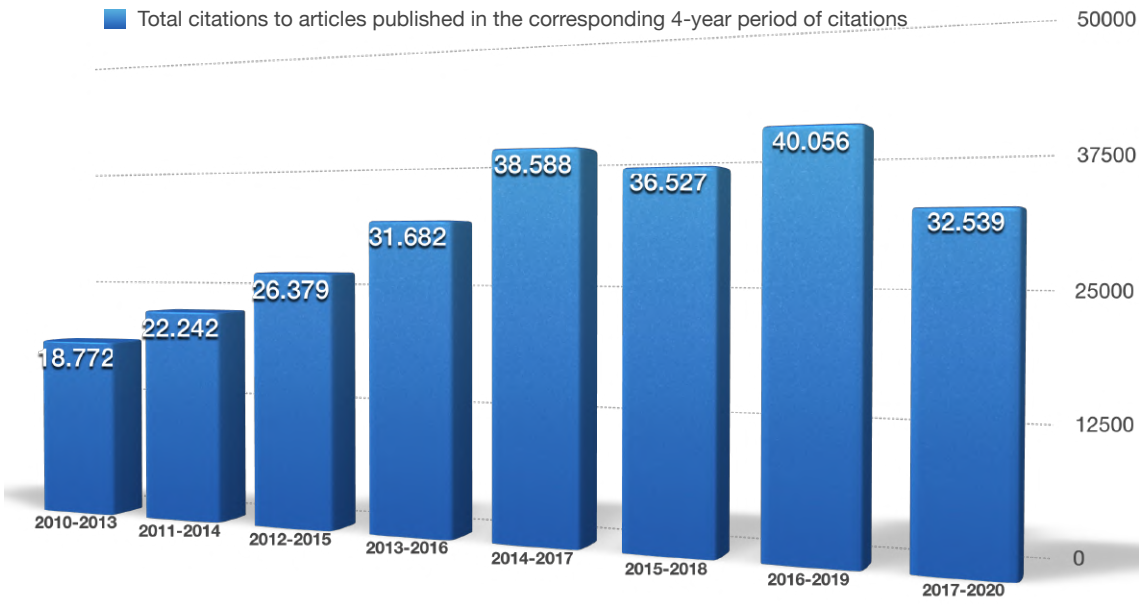


Figure 2.4: **Total number of citations during a given 4-year period received by articles published in the same period**.

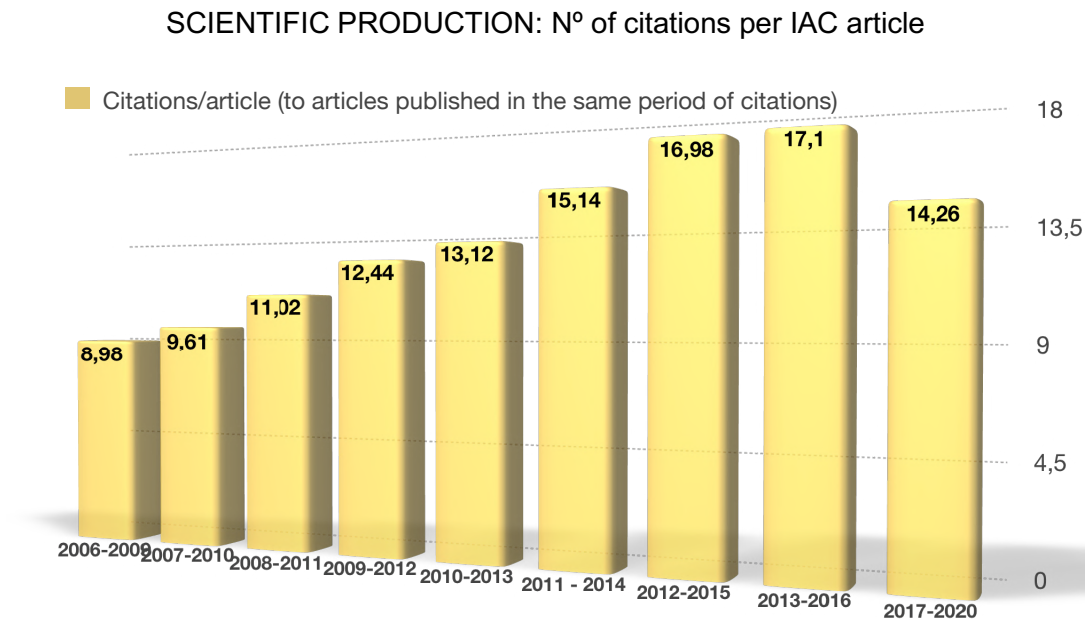


Figure 2.5: **Average number of citations per article published during the last decade.** This metric is calculated for other 4-year periods backwards in time to assess its evolution: We find a 90,5% increment of this ratio in period 2013-16 with respect period 2006-09.

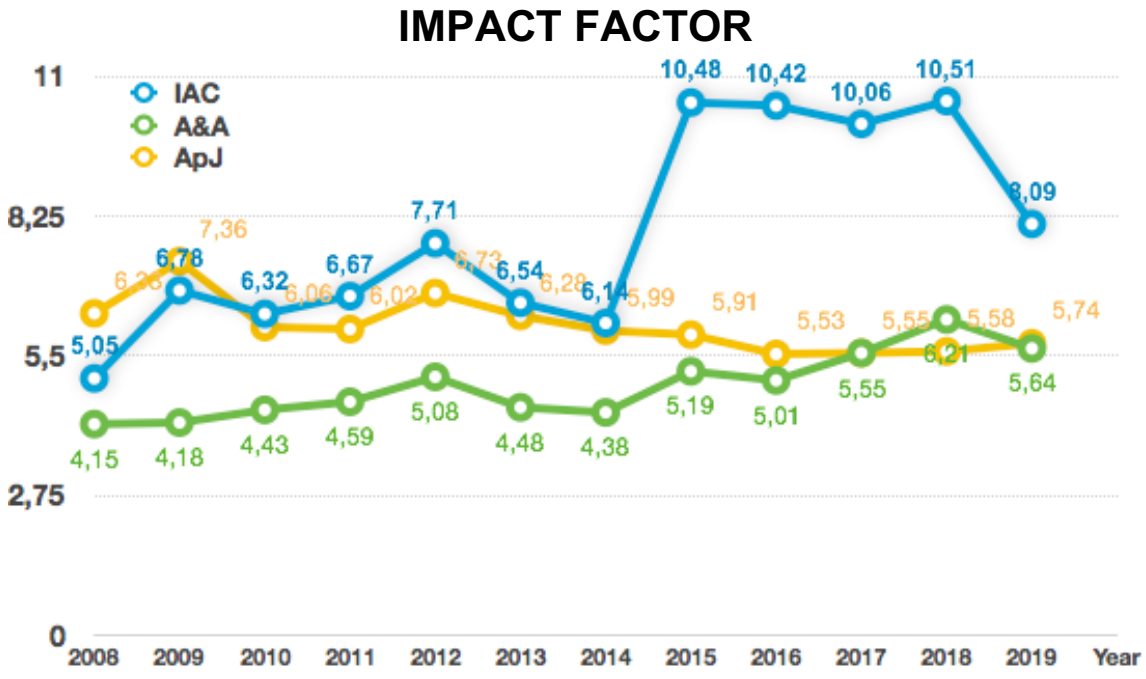


Figure 2.6: **Impact Factor of the IAC's scientific production.** The Impact Factor during the last 10 years has been over 6 with a remarkable increment in the period 2015-2018. For comparison, the Impact Factor of two reference journals in the field of Astrophysics (Astrophysical Journal and Astronomy and Astrophysics) has been in both cases lower than the corresponding for the IAC in the same year for the last 10 years

2.1.3 Instrumentation Division

The main objective of the Division is the development of astrophysical instrumentation projects that are promoted by the Research Division. To this aim the IAC's Instrumentation Division has the appropriate equipment, facilities and highly skilled personnel, enabling it to build much of the instrumentation for astrophysics in-house. The expertise of the division includes the following areas:

- Optical system design and testing
- Mechanical and opto-mechanical system design and development
- Cryogenic and vacuum system design and development
- Precision mechanics
- Adaptive optics
- Fibre optics
- Control systems
- Sensor characterisation
- Project management
- Systems engineering
- Electronic systems
- Software design and Laser communications

The Division is organized in two sections: Engineering and Production. Engineering comprises five departments: Project Management, Optics, Mechanics, Electronics, and Software. The Optics Department manages the three following laboratories: Optics, Fibre Optics, and Optical Coating. The Electronics Department manages the Electronic Design, the Electromagnetic Compatibility and the LISA (Laboratorio de Imagen-Sensores para Astronomía) laboratories and the electronic workshop. The Mechanics Department manages the Mechanical Integration laboratory and the CAD Room. Each engineering department is directed by a Head of Department, an IAC permanent engineer. The Production section, directed by the Head of Production, comprises the Mechanical Workshop, the Technical Drawing Laboratory, the Dimensional Metrology Laboratory and the Assembly, Integration and Verification (AIV) Room. The Division is directed by the Head of Instrumentation (Coordinador/a de Instrumentación), an IAC staff researcher appointed for a period of about 4 years who forms part of the IAC's directorate (Management Committee or Comité de Dirección - CD).

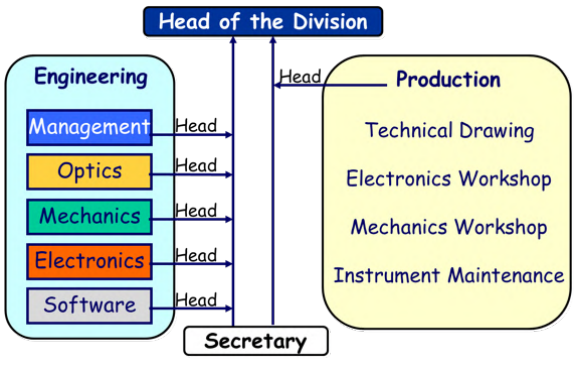


Figure 2.7: Schematic view of the matrix organisational structure of the IAC Technology Division. The main activity of the division is the development of instruments promoted by the researchers on the Research Division to support the Astrophysics science at the IAC.

The Division has a matrix structure (see Fig. 2.7); teams of engineers from the different departments are organized around a project manager to accomplish the projects. The Head of the Division, assisted by the heads of Departments and the Head of Production, assigns the permanent resources available and suggests the PIs the required staff recruitment to properly accomplish the instrumental project. The Head of the Division, assisted by the Technology Commission oversees the projects. This commission includes four researchers from the Research Division who lead instrument developments and two heads of department of the engineering section.

The activity of the Division is focused on the participation in large and international projects through consortiums with different international institutions. Among present projects under development are instruments for GTC, EST, VLT, EELT, WHT, as well as for several space projects. These instruments work at visible, infrared and microwave wavelengths. Currently, the Division is involved in around 20 projects of quite different scope (see Fig. 2.8).

PROJECTS	DETAILS	Type	Telescope	PI Institution	Total Effort Cumulative Engineering (2012-2020) Person-Year	Present Phase
EMIR		Camera, IR	GTC	IAC	47,8	
MIRADAS		Spectrograph, IR	GTC	U Florida	7,5	
FRIDA		Camera, IR	GTC	UNAM	6,5	
GTCAO-LGS		OA	GTC	IAC	43,9	
HORuS		Spectrograph, V	GTC	IAC	7,9	
EST-SOLARNET-MICAL-P.O.		Telescope	EST	IAC	48,4	
QUIJOTE		Microwave	QUIJOTE	IAC	51,2	
HARMONI		Spectrograph, IR	E-ELT	U Oxford	32,9	
WEAVE		Spectrograph, V	WHT	ING	13,8	
TTNN CONTROL UPGRADE		Telescope	TTNN	IAC	3,2	
CAMELOT2		Spectrograph, V	TTNN	IAC	0,2	
CSOA		Lab	-	IAC	0,4	
PLATO		Space	PLATO	CAB/IAA	6,0	
SUNRISE-3 & IMaX-3		Balloon	SUNRISE	IAA	4,8	
HARPS3		Spectrograph, V	INT	U Cambridge	2,9	
NIRPS		Spectrograph, V, IR	ESO 3.6	U Montreal	2,9	
ADFEMOS		Camera, V, IR	GTC	IAC	0,1	
LRS		Telescope	-	ESA	0,1	
NRT		Telescope	NRT	LJMU	0,2	
GROUNDBIRD LSPE-STRIP		Microwave	-	RIKEN/U Milan	1,6	
OPTICON H2020		R&D	-	UK ATC	7,8	
HIRES PHASE A		Spectrograph, V, IR	E-ELT	OA BRERA	1,5	CLOSED
ESPRESSO		Spectrograph, V	VLT	O Geneva	19,9	CLOSED
DIMMA		Telescope	-	IAC	1,7	CLOSED
EDIFISE		Spectrograph, V, OA	OGS	IAC	8,9	CLOSED
SOPHI (SOLAR ORBITER)		Space	SOLAR ORB.	MPS	7,2	CLOSED
NISP (EUCLID)		Space	EUCLID	IA Paris	4,6	CLOSED
AOLI (&FASTCAM)		Camera, V	WHT	IAC	5,9	CLOSED

Legend	
Type	
Camera	
Spectrograph	
Infrared	IR
Visible	V
Balloon	
Space	
Microwave	
Telescope	
R&D	
Adaptive Optics	OA
Phase	
Start	
Concept	
Preliminary	
Detailed/Fabr.	
AIV	
Commissioning	
End	

Figure 2.8: Summary of the instruments in development at the Technology Division in the period 2016-2020. Columns indicate: 1-Project name, 2-Type of instrument (see legend on the right), 3 -Telescope where the instrument will be installed, 4-Institution that led the development, 5-The cumulative effort (FTEs) at the IAC in that project for the period 2012-2020, and 6-The present phase of the projects development (see legend). The contribution/scope of the IAC varies significantly from project to project. Personnel of the Division also support the maintenance and improvements of the existing instrumentation at the Observatories, train technical staff and students, and contribute to transfer technology supporting IACTEC activities.

During 2020, four large projects concentrated ~66% of the engineering resources (GTCAO-LGS, EST-SOLARNET-MICAL, HARMONI and QUIJOTE). Other 13 smaller projects required about 31% of the engineering resources, 9 of them being developed through international consortia too. The participation in consortia provides many benefits to our engineers and researchers from many international exchanges.

Part of the engineering time is dedicated to activities such as organization and management, training or services. Organization and management include the managing of the departments, the time dedicated to the laboratories and its equipment, the technology demonstrator projects, and the participation in several committees or transversal activities of the IAC in

general, including support to IACTEC activities. Under Services we include the support to the Instrumental Maintenance group and small periods of time devoted to technical advice to other projects, departments or scientists.

2.1.4 Graduate Division

The Graduate Studies Division (GSD) at the IAC, working together with the Department of Astrophysics (DA) at the University of La Laguna (ULL), organizes and coordinates all studies on Astrophysics, including undergrad and graduate (Master's and PhD) degrees. Additionally, the GSD in collaboration with the IAC's Instrumentation Division is designing a new Master degree on Design Instrumentation for Astrophysics and Space. The Graduate Studies Commission (GSC), formed by five staff or postdoctoral members of the IAC, advises the Head of Graduate Studies and is in charge of the PhD student selection processes.

The IAC devotes an important part of its funds and human resources to support the realization of a PhD thesis as a full-time work. At present, there are 55 PhD students under contract at the IAC, a quarter of them non-Spanish nationals. The IAC maintains a long-term agreement with the University of La Laguna University (ULL) according to which the faculty members of its Department of Astrophysics are full members of the IAC and, in turn, the researchers of the IAC holding a PhD are formal members of the Department of Astrophysics. This has strong benefits for the PhD programme at the IAC since the PhD degrees are granted by the ULL and the research is fully done at the IAC. Between 10 and 15 new doctoral thesis are completed every year at the IAC.

Moreover, the IAC coordinates a series of activities addressed to the Graduate students and PhD community. The aim of these initiatives is to provide high-level training, as well as to foster collaboration between students and scientists. Among others, there are two main activities managed by the IAC:

- ✓ Canary Islands Winter School: It is an international school of Astrophysics organized yearly. It runs for two weeks and is aimed at PhD students and recently qualified Doctors in Astrophysics. 31 editions have been held.

- ✓ Summer Scholarship Programme: With these scholarships, the IAC provides an opportunity every year for 10-15 graduate students to gain an introduction to astrophysical research and technological development processes for instrumentation.

2.1.5 Observatories

The excellent astronomical quality of the sky over the Canary Islands – comprehensively characterized and protected by law – makes the Observatorios de Canarias (OOCC, the OT at Tenerife and the ORM at La Palma), an 'astronomy reserve' that has been open to the international scientific community since 1979, in accordance with the International Agreements for Cooperation in Astrophysics. These Observatories are one of the most productive and lowest cost astrophysical resource in the world available to Spanish researchers. The Observatories have attracted, over the last 40 years, more than 75 institutions of 27 countries to install their telescopes and instruments. This fact is a clear demonstration of the advantageous conditions offered by the host country.

The OOCC are the most important collection of observational facilities for optical and infrared astrophysics within the territories of the European Union. Other experiments for high-energy astrophysics and the study of the cosmic microwave background complete the battery of facilities available. The Observatories host first-class telescopes, such as the 10.4m Gran Telescopio CANARIAS (GTC), the WHT and TNG at ORM and the solar VTT and GREGOR at the OT. The European Solar Telescope (EST) shall be built at either the ORM or the OT. The CTA-North has started construction at ORM. The estimated total investment at the OOCC (telescopes and infrastructures) from its origin is more than 800 million euros, and in the years to come it will be possible to double this quantity if the TMT is finally built at ORM.

Different time allocation committees (TACs) award the telescope time available at each installation. Seventy-five per cent of this time is generally allocated to the national community of the countries that own or operate the telescope; 5% is allocated by the International Scientific Committee (CCI) to large international teams and major observational projects, and the remaining 20% is allocated to Spanish researchers by a TAC managed by the IAC. This time is considered the main return earmarked for the host country under the Agreements on Cooperation in Astrophysics.

The CCI is a management structure allowing effective participation in the decision-making process from the User Institutions at the OT and ORM. The IAC is responsible for the provision of basic and advanced infrastructures to these international organizations, as well as for the management of the aforementioned 20% Spanish time. The IAC also contributes greatly to the scientific exploitation of these facilities and operates its own telescopes. The

OOCC are managed within the IAC by the Vicedirector with the help of two site managers and about 25 staff who provide support for operations and administration.

Gran Telescopio CANARIAS, ORM. La Palma.

The Agreements on Cooperation in Astrophysics also include the exchange of information on scientific research in astrophysics; the exchange of scientists, experts and technical personnel; and the joint and coordinated implementation of programmes of technological research. Researchers from the IAC, representing an important fraction of the Spanish astrophysical community, have benefited very significantly from this agreement, and fruitful and long-term international collaborations have been established within its framework.

The Canary Islands benefit from exceptional astronomical quality as a result of a number of features. They are near to the equator yet beyond the reach of tropical storms; the whole of the northern and part of the southern celestial hemispheres can be observed from this latitude (approx. 28 degrees north); and the Observatories are located 2400 m above sea level, well above the temperature inversion layer produced by the trade winds. The predominant trade winds and the cold Canary current that bathes the islands result in a pleasant climate, and the troposphere is divided into two distinct layers through temperature inversion, causing the sea of clouds to become stabilized at about 1500m (Varela et al. 2008). The sea of clouds acts like a lid, keeping out atmospheric, particle and light pollution. In the upper layer the predominant winds are dry and turbulence-free, and the atmosphere is extremely clear with very low cirrus (high cloud) frequency (Vernin et al., 2011, PASP, 123, 1334). The night skies above the OOCC have been monitored and characterized over several decades (for a review, see Muñoz-Tuñón, 2002 and Muñoz-Tuñón et al., 2007).

In March 1992, a national law was passed for the Protection of the Astronomical Quality of both the Roque de los Muchachos and the Teide Observatories. The IAC Sky Quality Protection Technical Office regulates the application of this law and provides advice to local authorities on compliance.

2.1.6 IACTEC

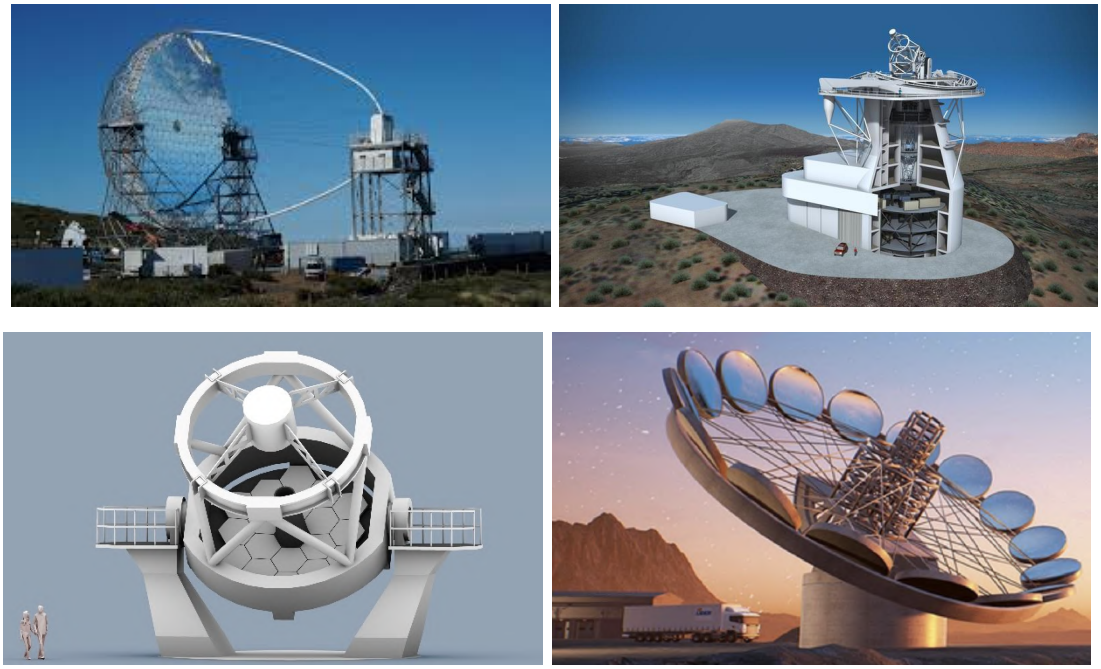
The IAC develops in-house a considerable part of the technology needed for astrophysical research activities. It has consequently acquired over time remarkable capacities in key areas of advanced instrumentation.

To exploit these long-standing capacities, involve the regional business sector and attract companies active in the sector of advanced instrumentation for astrophysics and space, the IAC has set IACTEC a hub element which connects the IAC technological know-how with those companies .

At the moment, IACTEC is developing four main lines of R&D&I: Large Telescopes, Space, Optics and Biomedical applications:

Large Telescopes: four projects are being developed in collaboration with international consortia. A total of 25 engineers (supported by external funding) are working for these projects under the supervision of 4 IAC permanent researchers. All these projects involve important contributions from international consortia made up by institutes distributed across more than 20 countries, and will be installed at the IAC Observatories:

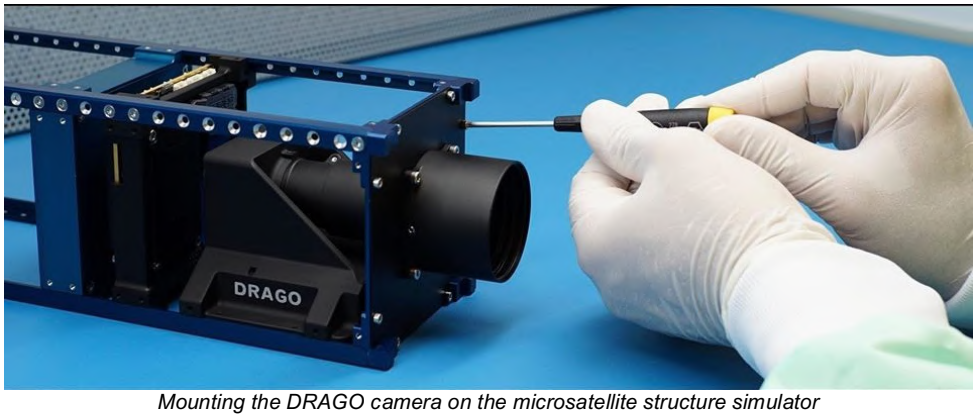
- **CTA** (Cherenkov Telescope Array), the world's largest network of telescopes for observing physical phenomena linked to the incidence of high-energy particles on Earth; under construction.
- **EST** (European Solar Telescope) the largest solar telescope in Europe and one of the two largest in the world; in the detailed design phase.
- **NRT** (New Robotic Telescope) the largest robotic telescope built to date in Europe, for the observation of phenomena that require high temporal resolution; in the detailed design phase.
- **ELF** (Exo Life Finder), an innovative telescope for high contrast imaging specialized in the detection of exoplanets; the ELF prototype (mini-ELF) is in the detailed design phase



IACTEC works on these Large Telescopes: CTA North (La Palma), EST, NRT and ELF

Space : three projects are being developed by 13 engineers with the tutoring of 4 IAC permanent staff.

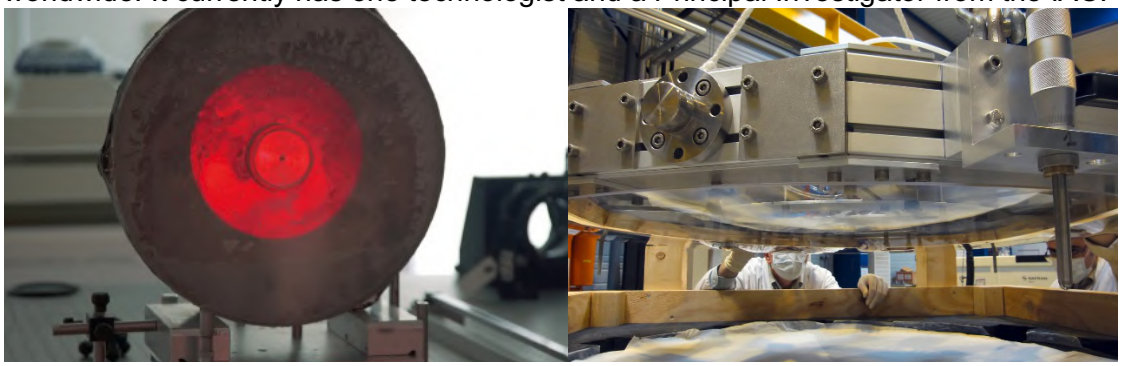
- Microsatellites: the development of small satellites for observations of the Earth and Space.
- Processing of Earth Observation Data: takes advantage of the synergies between the image processing techniques used in space and ground-based observatories.
- Optical Communications: to develop laser communication technologies between Earth and space.



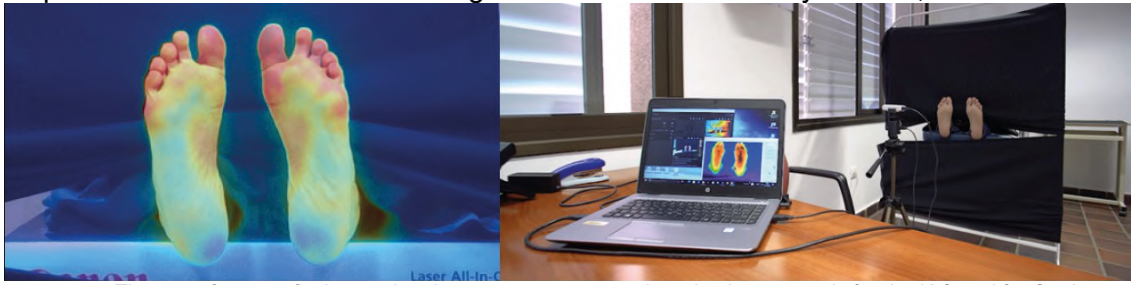
Mounting the DRAGO camera on the microsatellite structure simulator

Diabetic foot analysis with infrared thermography, IACTEC Medical Technology

Center for Advanced Optical Systems, a very recently launched project, aims to create a large optical component manufacturing centre in Tenerife, unique in Spain and competitive worldwide. It currently has one technologist and a Principal Investigator from the IAC.



Technologies for Biomedicine, the only single project here is being developed by 4 IAC technologists under the supervision of a principal investigator from University of Las Palmas de Gran Canaria (who is affiliated to IAC): based on image technologies widely used in astrophysics (infrared and microwave thermography), new diagnostic tools are explored to help the treatment of diseases of high incidence in the Canary Islands, such as diabetes.



The manufacture of advanced optics components up to 1.5m in size, strategic for the IAC and for Spain

IAC is creating specific laboratories for the last three technologies (Space, Biomedicine and Advanced Optical Systems), all of them with frontier capacities. To achieve this goal, 15 million euros have been awarded for laboratory equipment at IACTEC, to be executed until the end of 2022 (allocation from the Spanish Recovery Plan by the Ministry for Science and Innovation).

IACTEC activities are also partially funded by Cabildo de Tenerife (island government) through an Advanced Skills Training Programme awarded to the IAC which provides 16 contracts for engineers (each of a 4 yr duration).

2.1.7 Science Communication and Outreach

The IAC has wide experience on public outreach at all levels (from primary school to university degree). Open-doors, publishing of educational material, documentaries, exhibitions, radio programmes, etc., are common activities at the IAC. In fact, public outreach and training at different levels are also strategic objectives at this centre, which has been rewarded by numerous prizes for its science information and public education campaigns. The Unit for Communication and Scientific Culture (UC3) is responsible for these activities.

Currently, the permanent staff affiliated to the UC3 is composed of 6 people with the following professional profiles: a Head of Unit (journalist), an astrophysicist and science popularizer, a project manager, a web advanced assistant, a designer and a support secretary. It also has 3 people with temporary contracts to support outreach and education programs. The UC3 also trains each year a person with a summer scholarship. It also has external staff for various services in order to complete its functions, such as journalistic collaborations, management of social media and online platforms, specialized audio-visual works, technical maintenance and development of new website functions and media monitoring. It has an annual budget of about 200 K€ p.a. for general expenses and investments.

Communicating our scientific know-how and our technological ability, especially to future generations, is a fundamental aim of the IAC. Each year the UC3 produces more than 100 press releases, conducts more than 50 interviews and answers more than 350 media and production companies' requests. In 2015, the IAC coordinated the organization with all the Severo Ochoa Centers of Excellence, of the first 100xCIENCIA Forum, focused in "Communicating Frontier Science". The IAC is devoting special efforts to increase its presence in social networks, to track astronomical events for public outreach, and to produce audio-visual products explaining the IAC scientific research, challenges and outcomes, as

the "IAC Investiga" series, composed of five videos dedicated to the five research lines of the Severo Ochoa programme, and one video dedicated to Astrophysical Instrumentation.

Similar effort is devoted to the production of educational material and outreach activities for young students, the training of secondary school teachers from all over the country and from other European countries, to develop a dissemination plan in their regions with the goal to promote scientific and technological vocation in young students. For example, 80,000 students and 300 teachers from secondary and high school institutes from the seven Canary Islands have participated in the "SolarLab" project; they have been instructed by IAC staff about the Sun's astrophysical properties and the use of a solar telescope. The IAC also collaborates with the supervision of the Science Museum of Tenerife which receives the visit of many thousands of students every year and the new Visitor Centre at Roque de los Muchachos.

The UC3 also produces resources for the General Public (3D images, fulldome images, virtual visits) via the Network of Science Museums and Planetariums, cinemas, the tourist industry, etc. In addition, it creates exhibitions, such as "Luces del Universo" organized in 2015 on the islands of Tenerife and La Palma, on the occasion of the 30th anniversary of the IAC and the Observatories of the Canary Islands, which was visited by some 20,000 people.

The UC3 provides coverage and support to telescope inaugurations at the Observatories of the Canary Islands and at special events. With transversal projects, combining astronomy with other disciplines and subjects (literature, fashion, photography, music, theater ...), UC3 every year tries new strategies and resources of scientific popularization to stimulate the social interest for the Universe

2.1.8 General Service Management Unit

The General Services Management Unit (ASSGG) is responsible for the administrative, operational, human resources, library and institutional projects management, as well as technology transfer functions. It is divided into four sub-units or departments, supported by the secretariat, which houses the IAC registration office. The activity of these departments, and consequently the service to be provided, is developed on four fundamental principles: (1) users' orientation; (2) process optimization; (3) resources' efficiency; and, transversely, (4) e-administration, adapting our processes and relations with internal and external users by using IT tools, in compliance with the *TIC Strategy*[1] of the General Administration.

[1] A detailed Digital Transformation Plan is on force at the IAC for the period 2021-2023. It is briefly summarized under Action 32 of this Strategic Plan, and well aligned with the guidelines set by the State General Administration.

The budget executed every year by the IAC, and managed by this Unit, almost reaches EUR 30 million. This amount includes the internal core budget, provided by the IAC institutional members, as well as the external funding obtained under competitive calls. Every year[2] around 6.000 invoices are processed, for an amount of more than 12 M€; 7.500 payment orders are treated by the treasury department, for almost 28 M€; 2.000 travels for 1,3 M€; 550 new assets for 4,3 M€; 23 tenders committing 14 M€; 1.300 new acquisitions for 3,8 M€; and more than 400 entries or exists of goods from/to the Observatories.

Concerning external funds, more than 100 grants are justified every year. 60 formal requirements for further information or reports are yearly processed and an average of 4 financial-technical audits are passed. More than 50 new proposals for funding are supported, of which one third of them are usually approved for the amount of around 8 M€ on average.

From 5 to 10 minor or major infrastructure works are coordinated at the IAC HQ or at the Observatories every year, and almost 30 external services are contracted to the local companies (utilities, security, communications, cleaning, etc).

Selection and recruitment of new staff at the IAC, also responsibility of the ASSGG unit, is a major activity too. Every year around 75 new positions are offered to recruit new researchers, technicians or administrative staff. The HHRR sub-unit also coordinates occupational risk prevention activities, social plan, gender issues and staff training.

On the other hand, the Institutional Projects and Technology Transfer Office (OTRI) supports the IAC Directorate on the promotion and management of Institutional Projects with national and international entities, and focuses also its activity on supporting IAC researchers to obtain external funding, relationships with industries for the exploitation of our technological capabilities, the empowerment of the IAC and its observatories; and contact point with funding sources and other stakeholders related to RTD activities and policies.

This Unit provides also support to the IAC Directorate on the drafting and authorization process for signature of national and international agreements with third parties. Around 20 new relevant agreements are signed every year, related to the installation of new facilities at the observatories, development of new instruments or worldwide scientific collaborations.

The ASSGG unit houses also the library, to provide scientific information services to support the research and technological activity of the centre. In addition, since 2019, this unit is also leading the Digital Transformation Plan for the IAC and other additional tasks related to document and archive management.

Finally, the Secretariat provides administrative support to all these units and departments, including the management of the Registration Office at the IAC, with more than 3,000 registered documents every year, and another 2,000 official documents sent.

As part of the efforts from the ASSGG unit, to conveniently support the IAC in the development of research activities, technology developments, training actions, public outreach and operation of the Observatories, we foresee a set of supporting actions under this Strategic Plan for the period 2022-2025. These actions are summarized and described later in this document (actions from 32 to 35). They have been designed and planned to achieve significant improvements during the next years in some specific aspects:

The planned actions will focus on document management, the implementation of tools to improve the provision of digital services, basic training in e-administration, and remote working, among others.

[2] Based on 2019 figures, considered more representative than 2020 figures (due to COVID-19).

- To ensure a competitive labour structure, with a professional career, for researchers, technicians and administrative staff.
- To achieve a well-balanced distribution of our staff (researchers, technical and administrative staff)
- The most efficient management structure based on a project –oriented perspective, using performance indicators, and optimising services provided to internal and external users.
- To achieve the digital transformation of all our processes for a better service, including the implementation of the digital workplace, as a necessary step to teleworking.
- To work towards a more present corporate social responsibility in our day-to-day activity: environment, labour policies and fair governance.
- Private sponsorship as a relevant source to finance our research by valuing our related assets (scientific tourism, public outreach, technology transfer to other sectors, etc).
- To continue our efforts to obtain significant external funds from competitive calls at national but, specially, at international level

2.1.9 Main sources of funding

The IAC budget is made up from the contributions, provided by the Spanish National Administration and by the Canary Islands' Regional Government, and significantly complemented by external funding (an additional 90% on average), which is obtained mainly via competitive sources, agreements, bids and contracts. In 2020, the budget executed as the result of all these funds, was around 30,7 M€.

2020 IAC budget execution/ concept

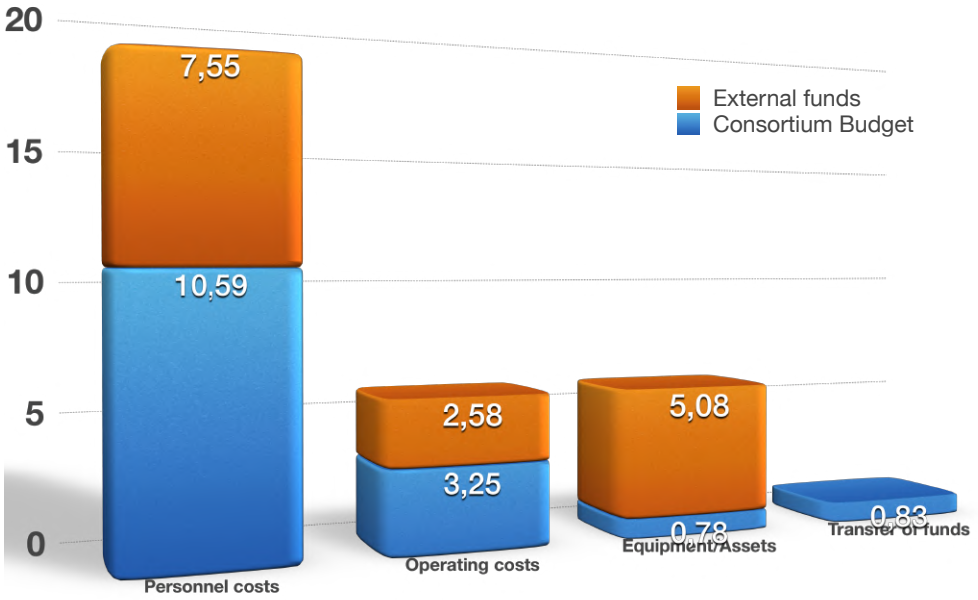


Figure 2.9

Consortium regular budget: State and Regional Administration Funding

The State and Regional Administrations provide 70% and 30% of our internal funding, respectively. During the last years these contributions have decreased due to the various national and international financial crisis. In 2008 the budget assigned to the IAC by these Administrations amounted to 12,6 M€ and 4,1 M€, totalling 16,7 M€. The budget for 2020 was 11,0 M€ and 4,56 M€ (15,56 M€), respectively. This means that 12 years later the annual budget allocated to the IAC was still 1,2 M€ lower.

The contribution from the Regional Government has slightly increased, but the corresponding contribution from the State needs to be speeded up in the coming years. The Recovery Plan from the Spanish Government has made a substantial allocation (9 M€) for IAC Investments in year 2021 which will compensate part of the budget reduction over the past decade. Later in this document we present more detailed information about these funds, as well as the resource strategy proposed.

Competitive Funding Sources and funds for the operation of the Observatories

The IAC competes in national grant funding rounds, as well as under international calls. The success rate varies significantly from one funding programme to another, as well as depending on the activity to be funded (infrastructures, research, training, etc.). On average, during the last ten years, 25% of this external funding is obtained from EU funding programs (2 M€/year), and 75% under national programmes. One new proposal for funding is prepared and submitted every week. More than half of them are approved, and around 10 million euro per year (on average) is being generated. Additionally, and related to the operation of the *Observatorios de Canarias*, another 2 M€ approximately are obtained in the framework of the International Agreement of Cooperation in Astrophysics and managed by the IAC every year.

The following chart, as an example, shows the expenditure of these external funds during 2020 broken down by funding source / programme.

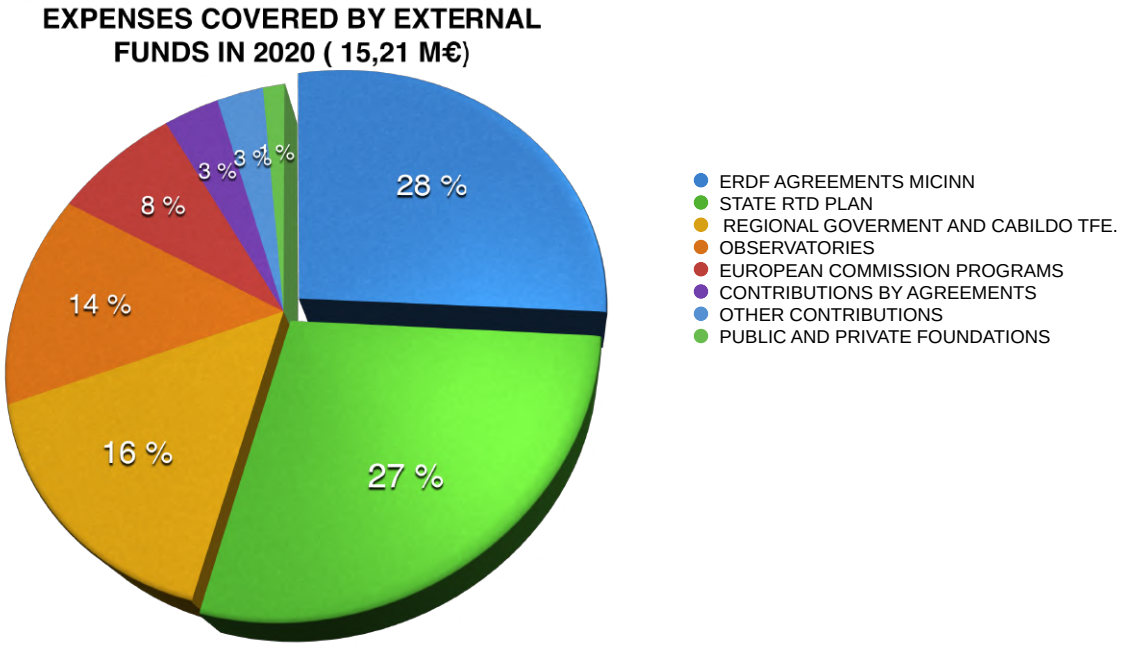


Figure 2.10

Around 40% of these external funds are provided to cover personnel costs, more than 35% to cover operating costs and the remaining is for new acquisitions and direct transfer of funds to partners.

The total amount of external funds received and spent by the IAC every year varies significantly, but we could assume around 10 M€ on average via competitive funding, plus those 2 M€ related to the Observatories running costs.

In general, the IAC has to capitalise better on the possibilities to receive different kinds of specialized funding which can be used for RTD, including ERDF funds. Involvement here means not just applying, but also being involved in the definition of strategies, priorities, and work programmes at a regional, national, and international level.

International collaborations and the IAC Research Programme.

The presence of international scientific institutions at the Observatorios de Canarias is articulated through the corresponding bilateral Agreements with the IAC which receives from these international partners and manages around 2 M€ p.a. in the form of contributions to the observatories' operating costs (the Common Services). Apart from these funds, there are also in-kind contributions (e.g. PhD or post-doctoral grants) as well as specific financial provisions in these agreements to directly support the IAC Post-doctoral Research Programme and promote the scientific cooperation with the signatory institutions:

- MAGIC Consortium
- University of Leuven (contribution in kind)
- University of Liege (contribution in kind)
- University of Turku (Finland)
- Royal Academy of Sciences of Sweden
- Qatar Foundation for Research and Development
- Las Cumbres Observatory Global Telescope Network
- University of Warwick
- University of Tokyo
- Kiepenheuer Institut fuer Sonnenphysik
- RIKEN Centre for Advanced Photonics
- The OPEN University
- Italian National Institute for Astrophysics (INAF)

Private Sponsorship and the IAC Research Programme

Finally, private entities also contribute to the Research and Training Program of the IAC with a total of approximately 280 K€ p.a. The most important contributors are:

- La Caixa and Fundación Cajacanarias: 250 K€ p.a. for the IAC PhD program
- Fundación Serra: 30 K€ p.a. for the IAC Visitors Programme.

2.1.10 International Dimension

International collaboration is one of IAC's defining characteristics and strengths, as a driver for ensuring world-class science and an enabler for broader socio-economic impacts. IAC is well integrated in the international community, participating in many of the main astrophysical projects and consortia and the related forums on RTD policies, in close relationship with national and international funding agencies and public bodies.

The vast majority of research articles produced by IAC, around 95%, are published with international co-authors. During the last decade, IAC has consolidated its international projection by attracting the construction of new major Research infrastructures (CTA, ASTRI, EST, NRT) that contribute significantly to the achievement of the New European Research Area (ERA), and also produce a ripple effect by stimulating other economic and social sectors.

International scientific collaboration in astrophysics and space

More than 60 collaborative agreements are active with institutions that operate facilities at IAC's Observatories and with other international consortia, including the STFC (UK), INAF (IT), the NAAWO, CNRS(F), INAOE and UNAM; the Universities of Aarhus, Turku, Tokio, Oxford, Liverpool, Leuven and Moscow; the Kiepenheuer Institute for Solar Physics, Leibniz-Institut für Astrophysik Potsdam (IAG) and the Max Planck Institute for Solar System Research; Caltech and Univ. of California on the scientific searches for dark energy with e-BOSS (SDSS-IV); the Univ. of Cambridge and Manchester on Cosmology (QUIJOTE); and the Univ. of Geneva (world leaders in the field of exoplanets), where our tight collaboration is reinforced in the framework of ESPRESSO, CoRot and space missions CHEOPS and PLATO. IAC also participates in AMS, MAGIC, ASTRI and CTA, major international astroparticle collaborations.

Other collaborations with international organisations and major consortia include:
European Southern Observatory (ESO)
European Space Agency (ESA)
Extremely Large Telescope (E-ELT)
Optical and Infrared Coordination Network (OPTICON)
European Association for Solar Telescopes (EAST)
High-Resolution Solar Physics Network (SOLARNET)
SOLAR ORBITER
EUCLID
Global Oscillation Network Group
WEAVE
CARMENES (CAHA)
Transiting Exoplanet Survey Satellite (TESS)
OSIRIS-Rex
Hayabusa2
Hera

IAC researchers have been involved in an extensive series of international research collaborations. These include large science teams involved in joint operations or development of facilities (such as Herschel, and Planck satellites, the IMAX experiment, and many instrument science teams for the GREGOR, VLT, ELT, and GTC). IAC leads some of these, but most importantly, those aiming at the scientific exploitation of the 10.4m GTC telescope on La Palma. In particular, IAC researchers are PIs of the instruments EMIR@GTC, QUIJOTE, TMS, OSIRIS@GTC, HORuS@GTC, GTCAO-LGS@GTC, GRIS@GREGOR, and Co-PIs of IMAX, CLASP, ARIEL and Hayabusa2 missions, FRIDA@GTC, ESPRESSO@VLT, WEAVE@WHT, Muscat2@TCS and SONG. They are also members of the Steering Boards of the consortia of space missions CHEOPS and EUCLID, and scientific committees of SDSS, CARMENES, NIRPS, HARPS3 and KESPRINT.

This multi-national collaboration is enriched because both the number of predoctoral and postdoctoral applicants for IAC research positions who are not Spanish nationals has slightly increased over the last years. In this sense, half of our new postdoctoral fellows are foreign nationals, 10% of them from non-EU countries. The same policies are enforced at the predoctoral level, and 25% of our new PhD students are foreign nationals (3% from outside EU).

IAC's researchers receive competitive funding awarded by, among others, the European Research Council (ERC) that supports investigator-driven frontier research across all fields, based on scientific excellence. IAC has been funded by EU over the past 25 years with more than 50 projects approved in diverse programmes. The IAC is recognised as one of the

Canary Islands Autonomous Community's key agents in the field of R&D&I with international projection.

A further boost to International cooperation is given by the strong Visitor programmes run by IAC's Research Division. These include

1. *Colloquia*, our top-level seminar programme, for which top international experts are invited to spend a week at IAC and give colloquia.
2. The Division's seminar programme usually two seminars per week on astrophysical research. Most speakers are from abroad, from other institutions in Spain or from IAC. The working language usually is English.
3. Workshops and conferences. Typically two major international conferences and 4-5 workshops are organised by the Research Division every year.
4. IAC's well known Canary Islands Winter School of Astrophysics has been running for more than thirty years.

IAC and its scientists play leading roles in many research and policy groups, boards, and committees, within Europe and elsewhere. On a personal level, many IAC researchers are members of international committees, e.g. on policy, time allocation, grants, or others, in many different countries.

Within the Observatorios de Canarias, IAC has lead the construction and operation of the GTC, the largest optical and near-infrared telescope in the world, including some of the first light instruments, in cooperation with Mexico and Florida University (US); contributes as a major partner (50%) in the construction of the CTA northern node; leads the European Solar Telescope (EST) and is a major partner for the New Robotic Telescope (NRT) and the Exo-Life Finder (ELF).

2.2 SWOT ANALYSIS

The IAC faces outstanding opportunities but also threats. How the national policies on RTD activities will be implemented in the coming years by the corresponding public departments, and specially the management and levels of financial contributions to support these policies, will be of paramount importance to recover the level of activity within the IAC that existed at the beginning of the current crisis.

S

STRENGTHS

- Internationally competitive RTD,
- Severo Ochoa Centre of Excellence
- Unique Observatories of excellent quality protected by law.
- Sustainable funding model, by national and regional governments.
- Strong support from regional society
- Success in external funding programmes.
- Access to leading facilities
- Reliable international agreements and collaborations.
- Appropriate critical mass of research staff
- Strong links with the University of La Laguna for advanced training of PhD students.

W

WEAKNESSES

- Located far away from science clusters in Europe
- Low RTD investment at national level.
- Limited flexibility of financial management and multi-year planning.
- Complex and lengthy administrative procedures.
- Lack of flexibility in permanent staff appointments and employment contract conditions.
- Lack of high-tech industry and private RTD in the region.

O

OPPORTUNITIES

- Attract new large Research Infrastructures (RIs) and scientific collaborations
- Development of new advanced instrumentation
- Astrophysics as a regional priority under the RIS3.
- IACTEC as a new hub to foster the private RTD sector.
- Synergies between ground-based and satellite observations.
- Attract external grants for RTD and high-qualified job creation
- Foster the development of HPC facilities at regional level.
- Become a key stakeholder in the development of Astro-tourism in the Canaries.

T

THREATS

- Funding below sustainability levels.
- Inability to manage funds in relation to the rules and temporary constraints.
- More competitors seeking for external funding.
- The aging of IAC workforce and lack of long-term stability of technical and support staff.
- Insufficient international commitment to construct and operate major RIs
- Lack of investments to accomplish an effective digital transformation plan

3. THE 2022-2025 STRATEGIC PLAN

3.1. Major Goals

The following major objectives are proposed for the period 2022 – 2025. These objectives need to be suitably coordinated and implemented by means of appropriate strategies and actions, as detailed in the following sections

3

Training and Social Commitment

Support of prominent RTD talent, promotion of best value for research infrastructures, public outreach and socio-economic development .

2

International Relevance

To promote a suitable framework of international collaborations with top-class RTD and innovation centres.

1

Research excellence and potential

To consolidate the IAC as a leading centre for astrophysical research.

2022-2025

Scientific and technological excellence is the overarching theme of our strategic plan

IAC aims to have a significant impact in Astrophysics and Space Science during the next decades by means of the following baselines: Conducting excellent RTD; building visionary strategic partnerships at international level; consolidating our Observatories as the European flagship for ground-based observations; training highly qualified people (researchers, engineers and technicians), agents of progress at the global level, who are capable of transferring their knowledge to society; strengthening IAC's commitment to reinforce social perception of science and its potential to generate socio-economic added value and last but not least, acting responsibly and ethically.

3.2. Strategies

The IAC will focus on eight complementary strategic directions in order to maximize the impact of its actions and the pursuit of its major goals for the period 2022-2025:

Strategy A: **A highly focused research programme capable of promoting talent and leadership** To achieve major advances in astrophysics, reinforcing the potential of current staff and developing the infrastructure to create new leaders in astronomical research fields, early identification of potentially outstanding researchers and providing them with the necessary environment and tools to compete on the international scene.

Strategy B: **The best value for major infrastructures and equipment.** To attract and maintain future and current world-class telescopes and equipment at the *Observatorios de Canarias*, increasing the quality and quantity of the access provided. To maintain and improve laboratories and workshops infrastructure to support instrument maintenance and development. Develop a strong body of support astronomers able to provide inter-disciplinary inter-project support to IAC research groups from software to hardware. Particular focus will be given to develop the potential to handle and carry out research with the large databases of present and future astronomical surveys.

Strategy C: **Fostering international research collaboration.** To improve the centre's international scientific leadership, strengthening collaboration with top research centres, universities and the coordination of international networks of excellence. Develop a set of measures that further increase the IAC's appeal as a host institution to recipients of major national and international grants and awards.

Strategy D: **Technology developments for astrophysics.** To increase leadership in advanced technologies of wide interest for astrophysics: cryogenics, high-spectral and high-spatial resolution, microwave polarimetry and interferometry, 3D spectroscopy, satellite payloads and general capacities.

Strategy E: **Training through RTD.** To continue developing the current Master in Astrophysics and Doctorate Programme, as well as training of engineers, supporting PhD students and summer programmes & schools at international level.

Strategy F: **Public Outreach.** To increase the international recognition of the IAC as a reference in the field of communication and dissemination of astronomy for a non-specialized audience.

Strategy G: **Advanced technology as a motor of socio-economic development.** To promote the valorisation and commercialisation of technology in astrophysics and other related high-tech fields.

Strategy H: **Improvement of the organizational efficiency**. To implement the Strategic Plan with adequate management tools, dealing with diversity in the workforce and coordinate employee efforts for better efficiency, and looking for methods to improve internal operations, eliminating inefficient and redundant processes, being open to adapt the organization to the new Public Administration requirements.

Making use of the corresponding colour for the major goals of the strategic plan we represent below how these strategies are related with one or more of the aforementioned specific objectives:
blue - excellence and potential;
green – training and social commitment;
yellow – international profile.

	Excellence & potential	Training and social commitment	International profile
Strategy A:	✓		
Strategy B:			✓
Strategy C:	✓		✓
Strategy D:	✓	✓	✓
Strategy E:	✓	✓	
Strategy F:		✓	✓
Strategy G:		✓	
Strategy H:	✓	✓	✓

3.3. List of actions

Research Programme:	
Action 1	**The magnetism and dynamics of the Sun.**
Action 2	**Exploring the diversity of Planetary Systems.**
Action 3	**Physics of Stars and the Interstellar Medium.**
Action 4	**Milky Way and Local Group galaxies**
Action 5	**Evolution of galaxies across cosmic times**
Action 6	**Very High Energy Astrophysics and Cosmology.**

Observatorios de Canarias:	
Action 7	**Enable world-class research**
Action 8	**Enhance the scientific support and technological capabilities at the Observatories**
Action 9	**Improve the quality and quantity of the services and supporting infrastructures of the Observatories**
Action 10	**Sky quality and environment protection**
Action 11	**Strengthening the science, technology and engineering skills and improving social perception.**

Gran Telescopio CANARIAS:	
Action 12	**Consolidating Gran Telescopio CANARIAS as the Spanish flagship in visible and IR observational astronomy.**

Technological capabilities:	
Action 13	**Creation of the IAC Data Center for Astronomical Surveys** **to** support data acquisition activities at the observatories; to develop data reduction and analysis pipelines; to undertake scientific exploitation of Big Data from major astronomical surveys using artificial intelligence
Action 14	**IAC Visualization Laboratory**
	SPECIFIC CUTTING-EDGE TECHNOLOGIES:
Action 15	**Cryogenic Technologies**
Action 16	**High spatial resolution**
Action 17	**High spectral resolution**
Action 18	**Free-Space Optical Communications**
Action 19	**New Detectors**
Action 20	**Microelectronics**

OTHER TECHNOLOGY STRATEGIC ACTIONS	
Action 21	**Participation in Large Space Observatories**
Action 22	**Optical/IR Instrumentation** To ensure leadership in the development of instruments for optical and IR astronomy.
Action 23	**Microwave Technologies for CMB Polarization and Spectroscopy** To ensure leadership in the development of instruments for microwave astronomy.
Action 24	**General capacities - Instrumentation** To ensure advanced capacities (human and material) for the Instrumentation Division
Action 25	**Development of the Center for Advanced Optics**

Training of researchers and engineers:	
Action 26	**Master and Doctorate. Summer programmes and schools** Supporting the Master and Doctorate in Astrophysics together with University of La Laguna, as well as the continuity of the Summer fellowships programme and the Canary Islands Winter School
Action 27	**Training through Research** Promoting the temporary recruitment of young postdocs/engineers, and their engagement on RTD projects
Action 28	**New Master degree: Design of Instrumentation for Astrophysics and Space**

Socio-economic development:	
Action 29	**Development of advanced technologies for optics and space sciences in collaboration with industry** IACTEC will be set up as a technological centre with the participation of private companies. Its activity will be focused on astrophysics, space and technology related fields.
Action 30	**New infrastructures: IACTEC and CATELP** New facilities are foreseen to be built, or already in process, for th

Public outreach:	
Action 31	**Public Outreach, Communication Media and Corporate Image** Improve communication and dissemination of the RTD activities. Develop new education programmes. Increase the presence of the IAC in the local, national and especially international mass media

Support actions:	
Action 32	**Towards a complete Digital Transformation**
Action 33	**Corporate Social Responsibility** Under this new programme the IAC will implement some actions on different aspects: environment; equal rights and appropriate labour policies; and fair governance.
Action 34	**Private Sponsorship** Develop strategies to attract private funding
Action 35	**Human Resources** 1) To adapt the current structure of support staff as envisaged by the new statutes; (2) to define and implement a new model for the temporary recruitment of young/senior researchers and engineers more consistent with international standards; (3) a well-balanced distribution of the IAC staff; (4) digital workplace and teleworking.
Action 36	**Updating the working scheme at the IAC** Lessons learned during the pandemic: improve remote working

ACTIONS
Brief Description

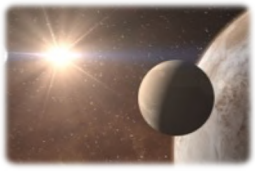
RESEARCH PROGRAMME

Action 1. The Magnetism and Dynamics of the Sun

Observe the physical structures and processes of the Sun and understand them in terms of the laws of dynamics, magnetism and radiation transfer, including the development of cutting-edge observational and computational techniques to reach those goals.

- Produce realistic one-, two- and three-dimensional models of key magnetic, dynamic and radiative processes in the solar atmosphere and convection zone using massively parallel computer facilities, in order to understand the physics underlying the solar structures and processes through suitable theoretical models.
- Carry out forward modelling from numerical simulations to bridge the gap between observation and theory, taking into account all the physical mechanisms that produce polarization in solar spectral lines.
- Develop novel diagnostic methods and inversion codes. Together with Bayesian inference tools, we will make a significant step forward on the quality of the information extracted from observations.
- Support space projects (e.g., CLASP, Solar Orbiter, Sunrise3) via new developments in observations and theory, including the modeling of the CLASP2 ultraviolet spectropolarimetric observations in order to study the magnetism of the upper solar chromosphere.
- Expand our understanding of the physics of the Sun by building a bridge between the knowledge gathered from solar observations and modeling, and the diversity of stars.

Strategic Objective:	**1,2,3**	Related Strategy:	**A, C, E**	Responsible Unit:	**Research Division**



Action 2. Exploring the diversity of Planetary Systems

Detection and characterization of giant and rocky planets around nearby stars, with a focus on planets in the habitable zone and systems around binary stars and unusual transiting components. Understanding the physical properties of asteroids, comets, transitional and trans-neptunian objects and the origin and evolution of the Solar System.

- Discovery of exo-Earths via radial velocity searches using the available guaranteed time of the IAC in state of the art high-resolution spectrographs, such as ESPRESSO, CARMENES, NIRPS and HARPS3.
- Measuring accurate planetary properties using observations of transiting planets around the closest and brightest host stars from TESS data and ground-based observatories (such as MuSCAT2 and SPECULOOS North), as well as from CHEOPS data for precise radius determination of the smallest exoplanets.

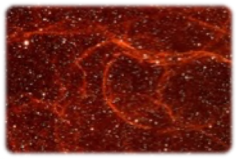
- Characterize exoplanet atmospheres with ESPRESSO, CARMENES and HARPS-N and JWST to push HeI, alkali and molecular detection from Hot Jupiters down to the super-Earth/mini-Neptune regime, and to contribute to the preparation of the ESA PLATO mission (expected launch in 2026).

- Develop an Adaptive Optics system for GTC based on a laser guide star (GTCAO-LGS), which will allow the direct detection and spectroscopic characterization of young giant planets.

- Study the atmospheric parameters and composition of planets' host stars including metal rich white dwarfs to shed light on the composition of the planets / asteroids engulfed during its evolution.

- To study the physical properties and composition of the minor bodies of Solar System, paying special attention to Near Earth Asteroids (NEAs), from the point of view of the planetary defense (Hera and DART missions) and the space exploration (OSIRIS-REx and Hayabusa2 missions), and primitive asteroids (using data from Gaia and JWST). We will also characterize new populations like the extreme trans-neptunian objects (ETNOs) or the interstellar asteroids and comets (e.g.,'Oumuamua andBorisov).

Strategic Objective:	**1,2,3**	Related Strategy:	**A, C, E**	Responsible Unit:	**Research Division**



Action 3. Physics of Stars and the Interstellar Medium

Understand the physics and life cycle of stars, from the most massive and luminous stars to the least luminous brown dwarfs which bridge the gap to the planetary domain, together with the interplay with the interstellar and circumstellar material in different environments and stages of stellar evolution.

- Provide observational constraints to compact binary evolution theories, black hole and neutron star formation models, and the physical processes driving accretion/outflow phenomena in interacting compact binaries.

- Provide a model independent empirical description of the properties of massive stars, from protostars to core-collapse supernovae and the progenitors of gravitational wave emitters, using high quality data from modern large spectroscopic surveys such as IACOB, OWN and WEAVE-SCIP, which will be complemented in a timely way with data from TESS and Gaia space missions.

- Discover and characterize new extremely metal-poor stars formed in the first few hundred million years after the Big Bang. The discovery will be done by mining large spectroscopic databases, such as SDSS, LAMOST, WEAVE, DESI, as well as photometric surveys as LSST.

- Understand the formation routes of complex nanocarbons like fullerenes and graphenes around evolved Sun-like stars, and their survival in molecular clouds and protoplanetary discs, using a highly interdisciplinary approach including astronomy, laboratory astrochemistry, advanced material science and quantum-chemistry, among others.

- Study the connection between the integrated spectra of local HII regions and their resolved internal structure. Understand the link between planetary nebulae and post

common-envelope evolution. Compilation and analysis of spectroscopic and photometric time series and 2D spectroscopy.

- Apply asteroseismic techniques to study the internal structure and dynamics along the evolution of solar-like stars from the main sequence to the red-giant branch. High cadence uninterrupted photometric data from the TESS, Kepler and K2 space missions, and ground based time-series spectroscopy obtained with the SONG network of telescopes will be of prime importance for this objective.

- Search and characterise ultracool dwarf stars and substellar objects with complementary techniques such as transits, radial velocity, and direct imaging to constrain models of formation and evolution using data from the Euclid and Gaia missions.

Strategic Objective:	**1,2,3**	Related Strategy:	**A, C, E**	Responsible Unit:	**Research Division**

Action 4. Milky Way and Local Group galaxies

Understand the conditions for the formation and evolution of the Milky Way and surrounding Local Group, and use them as probes to understand other galaxies at cosmological distances.

- Study the morphology, structure, chemistry, kinematics, dynamics and assembly history of the different Milky Way components using the aforementioned cutting-edge datasets and interpret these properties through modelling and cosmological hydrodynamical simulations.

- Derive time resolved star formation histories of the different components (thin and thick disk, bulge and halo) of the Milky Way, the Magellanic Clouds and other Local Group galaxies using Gaia, ground based wide field imaging and HST data, and study the stellar populations of the central Galaxy using EMIR and MIRADAS

- Study the internal kinematics and chemistry of dwarf galaxies, and determine their dark matter halo properties, by exploiting Gaia and forthcoming spectroscopic surveys.

- Study the multiple stellar populations phenomenon in globular clusters using CMDs for objects in the Milky Way and its satellites, and high-resolution, integrated spectroscopy in more distant Local Group galaxies

- Use Local Group galaxies as a stepping stone to study the distant and early Universe up to the reionization epoch

- Pave the road for the study of resolved stellar population work beyond the Local Group with ELT/HARMONI.

- Develop semi-empirical spectral libraries, stellar evolution model libraries and population synthesis tools, and validate methodologies using local stars, HII regions, PNe and galaxies, for use in the study of more distant galaxies.

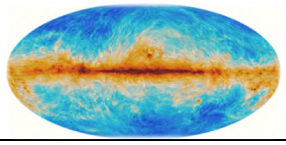
Strategic Objective:	**1,2,3**	Related Strategy:	**A, C, E**	Responsible Unit:	**Research Division**

Action 5. Evolution of galaxies across cosmic times.

Unveil the 3D structure, kinematics and stellar populations of galaxies to constrain models of galaxy formation in cosmological scenarios. Study the physics of star formation and the conditions of the interstellar medium over the history of the Universe and decipher the role of merging, accretion and supermassive black holes in the centres of galaxies.

- Identify the sources that reionized the universe one billion years after the Big Bang.
- Detect and study the first galaxies and quasars. Advance in our understanding of the nature and reality of dark matter. Investigate the low surface brightness universe to test dark matter predictions and galaxy formation theories.
- Study the physics of active galactic nuclei and supernovae feedback and their connection with galaxy evolution from the observational and theoretical point of view. Explore the multi-wavelength nature of feedback and investigate its impact on the host galaxies using data from GTC/EMIR, FRIDA and ALMA. Run the largest hydrodynamical cosmological simulations to date by developing star formation and feedback prescriptions that are designed to work at low resolution.
- Study the physics of star formation and the conditions of the interstellar medium over the history of the Universe and under different physical conditions. Survey the star formation history, and the structural, kinematic and chemical properties of the various components of nearby galaxies to probe models of galaxy formation and evolution in a cosmological context. Get ready for resolved stellar population studies beyond what currently possible, exploiting future instruments on ELTs, JWST and other major facilities.
- Explore different gas accretion mechanisms necessary for galaxies to keep forming stars. Image from the first time Intergalactic Medium gas flows funneling gas into local galaxies using GTC/MEGARA and WHT/WEAVE. Investigate the role of major/minor mergers and secular processes in galaxy evolution.
- Exploit unsupervised artificial intelligence to go beyond state-of-the-art data analysis techniques and get ready for big-data spectrophotometric surveys such as LSST, EUCLID, J-PAS and WFIRST. Improve the link between observations and theory by extracting and interpreting information from simulations of galaxies in a cosmological context spanning most of the Universe's life (e.g., EAGLE, ILLUSTRIS-TNG).

Strategic Objective:	**1,2,3**	Related Strategy:	**A, C, E**	Responsible Unit:	**Research Division**



Action 6. Very High Energy Astrophysics and Cosmology

To study cosmic- and gamma-rays sources, exploring the Early Universe, the dark ages and the nature of dark matter and dark energy.

- Astroparticle physics: study of cosmic-rays and gamma-ray sources with AMS, MAGIC, ASTRI and CTA. Understanding the origin, propagation mechanisms and chemical composition of cosmic rays. First science with the Large Size Telescope (LST1) of the Cherenkov Telescope Array (CTA). Contribute to multi-messenger astronomy with follow-up of transient events. Searches for annihilation of dark matter with the MAGIC telescopes and preparation for TeV science with CTA.

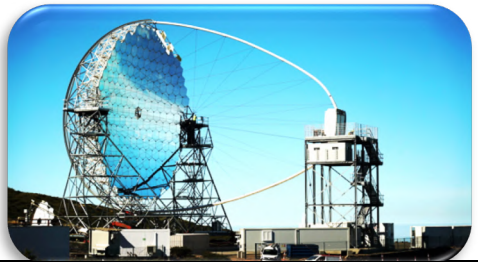
- Cosmic Microwave Background (CMB) studies on the Physics of the Early Universe, Primordial Gravitational Waves and Dark Ages. Obtain primordial B-modes constraints combining the CMB polarization experiments at Teide Observatory (QUIJOTE, STRIP, Groundbird, KISS) with Planck. Improving detectability of B-modes by future experiments like Litebird (JAXA) via new maps of polarized radio emission in the northern hemisphere and models of the radio foregrounds. Set constraints on the Epoch of reionization from spectral measurements of the CMB using newly developed instrumentation (TMS). Scientific preparation of future instruments to measure spectral distortions (SKA, space missions).

- Constraints on dark energy, dark matter, neutrino masses and time variation of fundamental constants with massive spectroscopic surveys (eBOSS, DESI, WEAVE, EUCLID, eROSITA, JPAS) and other probes. Constrain Cosmological parameters from measurements of the low redshift large-scale structure at $0.4<z<1.6$ with DESI and EUCLID, leading the determination of accurate error bars to BAO and Redshift Spectral Distortion measurements. Dark energy equation of state constraints and dynamical behavior determination using the new DESI Lyman alpha data. BAO reconstruction combined with cosmic voids to provide best BAO measurements. Study cosmic web around galaxy clusters using eROSITA data and JPAS data. Constraints on neutrino masses with Planck, galaxy clustering, Lyman alpha forest and galaxy clusters with DESI, EUCLID and WEAVE. LCDM model tests using the Integrated Sachs-Wolfe effect. Searches of ultra-light bosonic particles: axions and dark photon emission from stellar evolution considerations (e.g., Tip of the Red Giant Branch) and improved constraints from microwave polarimetry.

Strategic Objective:	**1,2,3**	Related Strategy:	**A, C, E**	Responsible Unit:	**Research Division**

OBSERVATORIOS DE CANARIAS

The Strategic Plan of the Observatories (OOCC) is included as a specific annex to this document where we propose a very ambitious plan for the period 2021-2024, endorsed by 5 complementary strategies which are considered here as actions, with a total of 27 sub-actions:



Action 7: **ENABLE WORLD-CLASS RESEARCH**

by facilitating and supporting the installation of forefront international telescopes with major investments in their construction and instruments

- **The Cherenkov Telescope Array Northern Observatory (CTA-N)**
  CTA comprises two sites, one in the northern hemisphere at the ORM, and one in the southern hemisphere near ESO's Paranal site in Chile. The CTA baseline array layout foresees the construction of 4 large-size telescopes (LST) and 9 mid-size telescopes (MST) at the ORM site. The 4 LST and 5 MST are expected to be completed by end of 2024, and the remaining four MST at the ORM site are planned to be ready for operation in 2026.

- **The European Solar Telescope (EST)**
  The European Solar Telescope (EST) is aimed to be the worldwide leading 4,2-meter class instrument dedicated to study fundamental processes shaping magnetic activity of the Sun. Thanks to the progress carried out so far by the EST Consortium and the Project Office led by the IAC, the detailed design is in advanced status. The goal is to present the funding authorities a final Construction Plan in 2023, this further design works need to be implemented. Due to its expertise, the IAC is interested on (1) the development of a spectrograph for EST that will operate in the near-infrared with an IFU-based on image slicers, (2) contributing to the design of the EST MCAO system and (3) providing the EST Construction Project.

- **The New Robotic Telescope (NRT)**
  NRT will be a 4-metre class, optical telescope feeding several instruments, optimized for rapid-response and high cadence observations of variable and explosive objects. NRT will provide a variety of capabilities to explore the wealth of transient targets in the night sky and test the physical processes that create them. Such rapidly varying objects are too challenging for existing telescope facilities to observe effectively. NRT is starting the detailed design phase. The main contributions from IAC are related to the manufacturing of the telescope optics, the development of the robotic control software, the telescope opto-mechanics and scientific instrumentation.

- **New technology hybrid optical telescope (mini ELF)**
  This will focus on the development of the miniELF at Teide Observatory that will serve as a technology demonstrator for the much larger ExoLife Finder, which is proposed to be built with an effective diameter of about 30-40m. miniELF will feature 15 mirrors of 0.5m in diameter, each with a small, elliptical secondary mirror; mounted on a "bicycle wheel" support structure of 3.5m in diameter which will be lightweight and simple to construct. We now have a conceptual design for miniELF which provides optical, mechanical, and electronic solutions with bottom-up cost estimates and plan to finalise the full detail design in 2021 and enter construction in 2022.

- **TOT4 – Optical IR ROBOTIC TELESCOPE FOR THE OT**
  The aim of this action is to develop a modern, state-of-the-art segmented 4m-class IR wide field telescope to be used in normal, remote and robotic modes. The inclusion of such a telescope among the pool of facilities to which the Spanish community has access at the Observatorio del Teide (OT) would give a leap in quality both to the astronomy carried out there and to numerous research and instrumental programs in which the Spanish astronomers are involved. We aim to conclude the detailed design of the telescope before 2025.

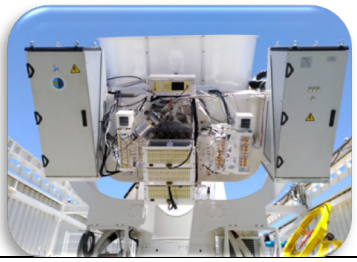
- **DETAILED DESIGN OF A DARK MATTER TELESCOPE**
  Axion detection would be one of the most important moments in the entire history of Science. The Dark-photons & Axion-Like particles Interferometer (DALI) is proposed for the search for the quantum chromodynamics (QCD) axion in the poorly explored 25-250 μeV range, or equivalently 6-60 GHz. The aim of this action is to complete the detailed design of the DALI telescope over a 3-year period.

- **AN ATLAS NODE AT OT FOR PLANETARY DEFENSE**
  ATLAS is an asteroid impact early warning system developed by the University of Hawaii and funded by NASA. The installation of an ATLAS telescope in the OT will position the OT at the head of Planetary Defense. It will increase the international visibility of the observatory and facilitate access of the IAC researchers to the survey results. The objective of this proposal is to achieve the installation of an ATLAS telescope in the OT contributing with two important components, the detector and the dome.

- **UPGRADE OF THE COSMIC MICROWAVE BACKGROUND LABORATORY (CMBLAB) AT OT**
  The CMB group at the IAC leads the QUIJOTE and Tenerife Microwave Spectrometer experiments, which are part of the CMBLAB at Teide Observatory. QUIJOTE aims to characterise the polarization of the CMB and other physical processes, Galactic or extragalactic, emitting in the microwave range and TMS (Tenerife Microwave Spectrometer) is an ultra-high sensitive spectrometer in the 10-20 GHz range, that will accurately measure absolute distortions of the sky spectrum. The main proposed CMBLAB actions are related to investments on: the QUIJOTE telescopes and auxiliary equipment, the TMS dome and auxiliary equipment and funds to implement the Conceptual design of the European Low Frequency Survey telescope (8-10 m antenna) and its instrumentation.

- **ASTRI MINI-ARRAY of gamma-ray telescopes**
  ASTRI is a Flagship Project mainly financed by the Italian Ministry of Education, University and Research, and led by INAF, the Italian National Institute of Astrophysics. The OT will host an array of 9 SSTs (4m each) during the implementation of the present Strategic Plan. This array will complement CTA-N at higher energies.

Strategic Objective:	**1,2,3**	Related Strategy:	**B, C, D**	Responsible Unit:	**Sub-direction**



Action 8: ENHANCE THE SCIENTIFIC AND TECHNOLOGICAL CAPABILITIES OF THE OBSERVATORIES

support the development of key technologies, extend collaborations with research groups, pursue international contracts, and recruit and retain outstanding skilled staff, to keep the Observatories at the forefront of world-class astronomical instrumentation for both national and international telescopes.

- **PROMOTE LEADING ASTRONOMICAL INSTRUMENTATION: HARPS3**
  HARPS3 is the next generation instrument for the 2.5m Isaac Newton Telescope (INT) located at the ORM. The IAC technical contribution to the HARPS3 project includes the preparation and conditioning of the Coudé room and thermal enclosures of the instrument.

- **PROMOTE LEADING SOLAR INSTRUMENTATION: MULTI-LINE INTEGRAL FIELD UNIT SPECTRO-POLARIMETERS FOR THÉMIS AND GREGOR**
  To achieve the precise determination of the thermal and magnetic conditions of the Sun's outer atmosphere unique observations are required: high precision spectro-polarimetry of a two-dimensional area of the solar atmosphere at different spectral lines with high spatial resolution. It is proposed the design, fabrication and installation of an IFU in THÉMIS and the installation and commissioning of an existing IFU in GREGOR

- **UPGRADE THE OGS AND PRODUCTION OF PILOT INTERFERENCE FILTERS FOR WIDE FIELD SURVEYS**
  This action foresees to upgrade the OGS telescope by installing a new field corrector and filter wheel. These actions will transform the OGS into a powerful wide field facility (the only one left at the OOCC after the recent instrumental actions on the WHT and INT), thus boosting the scientific capabilities of the telescope and, thus, of the OOCC.

- **MICROWAVE TECHNOLOGIES FOR CMB POLARIZATION AND SPECTROSCOPY**
  Microwave Spectroscopy and polarimetry are the fundamental measurements carried out within the Cosmic Microwave Background studies at the Teide Observatory. The Tenerife Microwave Spectrometer (TMS), which will carry out Spectroscopy in the 10 – 20GHz frequency band and will be a prototype for future ground-based and space instruments. Spectroscopy is seen as a key area of research for the CMB group and strategic investments are required to upgrade the instrumentation at CMB Laboratory.

- **INSTALLATION OF A QUANTUM KEY DISTRIBUTION EQUIPMENT AT THE OGS TELESCOPE**
  Optical communications in space have been identified as a key technology for present and future information transmission between satellites and with Earth. The OGS telescope has a long history of uses in the field of the optical communications in free-space. The objective of this action is to provide the necessary upgrade to become a reference in the reception of quantum key distribution from satellites, a field which is nowadays being strongly pushed in Europe, and which has a clear commercial future.

- **TCS UPGRADE IN THE AGE OF TIME DOMAIN ASTRONOMY**
  The passage of the years has made the control system and elements of the 1.5m TCS telescope obsolete, and an update is urgently needed for the scientific use of this telescope. The current dome suffers from very important structural problems that cause it to fail several times every night. This is fatal for time domain astronomy, where long and stable series of observations are needed. The conditions of the Observatorio del Teide and the available instrumentation make TCS very important in the category of

medium-sized telescopes. Instruments like MuSCAT-2, FastCam or ALIOLI are unique and offer a relevant annual scientific output, as well as crucial technological developments.

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- **DEVELOPMENT OF A LASER GUIDE STAR LAUNCH SYSTEM**

  The astronomical seeing conditions on a given night at a given location describe how much the Earth's atmosphere perturbs the images of stars as seen through a Telescope. Adaptive optics (AO) solves this problem by combining the latest technologies to correct for distortions introduced by the atmosphere. To do this, the AO system needs the light from a sufficiently bright star that is close to the target in the sky as a reference, or alternatively, produced by an artificial star (the laser). This major upgrade is necessary to duly support the coming era of instruments at the OOCC.

- **PARTICIPATION IN SCIENTIFIC INSTRUMENTS FOR THE THIRTY METER TELESCOPE (TMT)**

  One of the IAC's undertakings in the TMT installation agreement is to collaborate in its program of first light instruments from the moment the TMT takes the decision to install the telescope at the ORM. The TMT has selected three early light instruments: a wide-field, multi-object spectrograph working at optical wavelengths called WFOS; an integral-field unit spectrometer with imaging capability working at near-infrared wavelengths called IRIS; and a multi-slit, near-infrared spectrometer with imaging capability called IRMS. The construction phase could be accomplished by the end of 2029.

Strategic Objective:	**1,2,3**	Related Strategy:	**B, C, D**	Responsible Unit:	**Sub-direction**

Action 9: TO IMPROVE THE QUALITY AND QUANTITY OF THE SERVICES AND SUPPORTING INFRASTRUCTURES AT THE OOCC.

The OOCC will strive in guaranteeing the adequate performance of general purpose infrastructures at both observatories (access, telecommunications, electricity, water supply and sewerage, residence and other support installations), simplifying logistics for the scientific institutions working at the observatories

- **ELECTRICAL SYSTEM IMPROVEMENTS ON TEIDE OBSERVATORY. RING CONFIGURATION.**
  The Teide Observatory has an "antenna" or "branched" high voltage network. The network begins at the Sectioning Center located outside the Observatory. The nominal maximum capacity of the Observatory is currently 700 kW, working over 80% of this capacity. The present system has several problems that could endanger the scientific operations and hampered the implementation of future infrastructures. The proposed action is to develop a ring high voltage network and expand the Observatory's capacity to 1,250 kW, increasing the power of the Transformation Centers, getting the necessary power for future telescope installations.

- **OOCC DATA NETWORK IMPROVEMENTS**
  Each Observatory (OT y ORM) already has a fiber footprint without redundancy, however for new projects is very important to have an alternative way to reach it. This can be achieved by a new fiber footprint using additional ducts and paths for bringing to the telescopes a high availability network. The requested action include: (1) Renew some network devices ready for 10G interfaces; (2) Fiber deployment in the new canalization at the ORM; (3) Improvement in the canalization of the fiber segment that goes to the ORM and (4) continue building canalization and fiber sections at OT.

- **IMPROVEMENT OF THE SECURITY FACILITIES AT OOCC**
  In order to handle emergency situations and provide a better security service, both sites require cameras, software and mobile stations that will be set-up as a integrated system connected to the IAC's Headquearter.

Strategic Objective:	**1,2,3**	Related Strategy:	**B, C, D**	Responsible Unit:	**Sub-direction**

Action 10: SKY QUALITY AND ENVIRONMENT PROTECTION

The OOCC will work continuously monitoring the quality of the sky and updating the technology and tools according to the new needs and opportunities. The OOCC are also committed to protect the exceptional quality of the Canary Islands' sky, so that astronomers can continue to pursue world-leading science with telescopes already in operation or to be located there, assuring at the same time appropriate preservation of surrounding environment.

- **PRESERVE NATURAL NIGHT SKY BRIGHTNESS OF OOCC**
  The natural night sky is never completely dark. The loss of darkness due to the increasing use of the artificial light at night has a dangerous, but sometimes neglected, impact on natural ecosystems. Evaluating the effects of ALAN on the night sky brightness (NSB) on dark places requires extensive ground-based observations. The main goal of the proposed action is to acquire night photometers and all-sky cameras to monitor and preserve natural NSB of Canarian Observatories.

- **GLOBAL ENVIRONMENTAL ANALYSIS & MONITORING PLAN OF THE OOCC**
  This action will focus investment in two complementary issues: regulations (Knowledge & enforcement of environmental regulations affecting the OOCC) and the application of measures to ensure environmental and sustainable management in accordance with environmental awareness, including the Preparation of initial study, scope and targets, Elaboration of Environmental Monitoring Plan, Updating the waste plan for OOCC, development of the recycling point's area for temporarily, and centralized management for the various institutions and facilities operating in the OOCCs.

- **SUSTAINABILITY, EFFICIENCY AND ENVIRONMENTAL PROTECTION**
  The reference framework for achieving an improvement in the OOCC sustainability, is based on some key features, like, Energy, Waste and Sustainable and Responsible use of water and other resources. This action will address Developing the photovoltaic park on the roofs of the Residence and Common Services building with about 200KWp, to be implemented in the next years, Installation of windmills in wind farms, to compensate the power consumption of the OOCC, Waste management (hazardous and non-hazardous) and completion the zero discharge project of waste water after purifying at ORM, its reuse and the development of fire protection networks in both Observatories, including the use of rainwater

- **DEFINITIVE CHARACTERIZATION OF THE BOUNDARY LAYER AND MONITORING NEW OPERATIONAL PARAMETERS**
  To maintain OOCC among the best Astronomical Observing sites we will implement new tools and instruments. Specific tasks will develop the software to provide databases worldwide, implement algorithms of forecasting, develop the software to automatize the operation and complementary studies on the sodium layer for laser guide stars. Furthermore the Sky Quality Group will support and provide specific advise to attract important facilities to be installed at the observatories implementing specific task such as the compilation of atmospheric valuable information, provide new data and develop taylor-made analysis for each case

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Strategic Objective:	**1,2,3**	Related Strategy:	**B, C, D**	Responsible Unit:	**Sub-direction**

Action 11 STRENGTHENING THE SCIENCE, TECHNOLOGY AND ENGINEERING SKILLS AND IMPROVING SOCIAL PERCEPTION.

The OOCC will assist students at every level and make the public aware of its scientific, technological and engineering achievements in astronomy. The OOCC will attract and retain highly skilled employees, and use its research and technological environment to enhance and broaden technical training and capacity within the workforce of the Observatories. Moreover, it will ensure a more active involvement from the society of the region, increasing awareness on astrophysics and improving social perception.

- **COMMUNICATION TO GENERAL PUBLIC & VISIBILITY OF OOCC**
  To achieve a consolidated international projection of the observatories we will foster the dissemination of key features and main outcomes on online social platforms and other applications (virtual visits, presence in massive impact tools...): Likewise, bearing in mind that the OOCC are a meeting point of the international astronomical community and, therefore, annually receives visits from scientists from all over the world, either from the field of astronomy or from other areas of knowledge, we will employ professionals meeting all the demands of information and management, which would translate into a good image and prestige of the ICTS.

- **Coordination and Management**
  The scope of this action is to ensure a proper implementation of the Observatories Strategic Plan in accordance with administrative, financial and legal issues defined by the ERDF regulations and national guidelines. Some of the tasks assigned to this action will be reporting to the IAC Steering Committee to ensure the overall success of the Observatories Strategic Plan (completed on time, within budget, and with the best possible quality), managing the Plans' resources; developing the proposed strategies, and assuring that system documentation is kept up to date using a formal work configuration control process

Strategic Objective:	**1,2,3**	Related Strategy:	**B, C, D**	Responsible Unit:	**Sub-direction**

GRAN TELESCOPIO CANARIAS

This action is mainly carried out by GRANTECAN

Gran Telescopio CANARIAS, ORM. La Palma.

Action 12: Consolidating GTC as the Spanish flagship in visible and IR observational astronomy

The aim of this action is to support GTC in the implementation of some specific activities:

- To maximize the telescope time available to the GTC users and the quality of the science data obtained with it.
- To complete the telescope capabilities from the basic telescope initially built.
- To incorporate new science instruments to expand the interest of the GTC for the science community (EMIR; HORUS; MEGARA; GTC-AO; MIRADAS).
- To incorporate new partners to the GTC to increase the internationalization and improve the budget.
- To affect positively the culture and economy of the region and, in particular, of the Island of La Palma.
- To maximize the results of the previous objectives within the limited budget available.

TECHNOLOGICAL CAPABILITIES

Action 13. IAC Data Center for Astronomical Surveys

The aim of this activity is to create a dedicated unit within the IAC for the acquisition, treatment and development of tools for the scientific exploitation of Big Data coming from the major astronomical surveys the IAC is involved in.

The traditional model of observational astronomy, where the most expensive component is the telescope, followed by its instruments, and finally the software and infrastructure to analyse them, has become obsolete. Most of the new large astronomical projects invest almost as much in instrumentation as in telescopes, and a considerable fraction of this investment is devoted to human and technical resources for data acquisition and processing, a crucial stage for scientific exploitation.

The most productive observatories in the world are at the forefront for their capacity to develop the required infrastructure to handle the large volumes of data they generate. Observatories like HST, SDSS, Keck or ESO have made huge investments in this aspect. The end products go beyond completely reduced and calibrated images or spectra, and include high-level products also, which greatly shortens the effort required to carry out. It is easy to see that a researcher who has to acquire, reduce, and analyse data necessarily has a much lower efficiency than one who starts with data pre-processed in an optimal way.

The goal of this action is to set up a transversal group helping us facing the new challenges in Astrophysics research with the arrival of the numerous major astronomical surveys the IAC is part of. The creation of the group will go beyond our own field and will foster inter-disciplinary interactions with researchers confronting similar problems in other fields. The seeds for this initiative have already been planted. At least 4 postdoctoral positions have recently been dedicated to the development of software for data processing in the HORuS, EMIR, APOGEE, WEAVE, Euclid projects, and in general for Big Data and Machine Learning. Servers with almost exclusive dedication have also been acquired for ESPRESSO or WEAVE, and a call for a specialist technician has been opened.

These are all important steps, which have been relatively uncoordinated so far. The IAC strives to become the reference institution attracting interest from other research institutions and industry in Spain to develop a broad range of actions, including training activities at different levels. In the context of this strategic plan, we propose to:

- Build a group of technicians and researchers dedicated to these developments in a unit, so that synergy occurs among them
- Provide that unit with an experienced coordination team that supervises the work and optimizes the use of human resources
- Improve the infrastructure available at the IAC for the systematic processing of data from our instruments and observational projects.

This group will:

- support data acquisition activities at the observatories
- develop data reduction and analysis pipelines
- support the scientific exploitation of Big Data using artificial intelligence techniques

The necessary structural changes to make this initiative a success can be undertaken in the medium term (i.e., a couple of years). The infrastructure requirements will benefit, in the short term, from the availability of recovery funds for infrastructures, which will be dedicated to the acquisition of powerful computer servers that would be used in the context of the WEAVE, DESI, Gaia, Euclid, or HARMONI projects.

Strategic Objective:	1,2,3	Related Strategy:	D, G, H	Responsible Unit:	Research Division

Action 14 IAC Visualization Laboratory

The goal of the IAC Visualization Lab (IVL) is to develop and exploit new visualization techniques for astronomical data and numerical simulations in astrophysics. The outcome should help the IAC staff to a) gain insight on the physical process that govern the universe, b) educate young researchers, c) reach out to the public and communicate new discoveries in astronomy.

Our perception of the world is dominated by sight, followed far behind by the rest of the senses, as exemplified by the popular saying “an image is worth a thousand words”. Science has expanded dramatically our ability to “see”, in the widest sense, but as scientists we are well aware of the importance of an appropriate representation of data to detect patterns that have been missed before. In addition, it is undeniable that high-quality images of the sky are the best vehicle for astronomy outreach.

Audiovisual technologies have been continuously advancing and nowadays provide us with the means to examine images in a gigantic format, on projectors or TV screens with very large sizes but modest resolution, or with high resolution over a very limited area (e.g., mobile phones, or ultra-high quality computer screens). In our daily lives, however, we do not regularly encounter images with the combination of wide-area and high resolution. This is only possible with matrices of high-definition computer screens, which individually are not larger than 32”, but can, combined, display images that span tens of square meters.

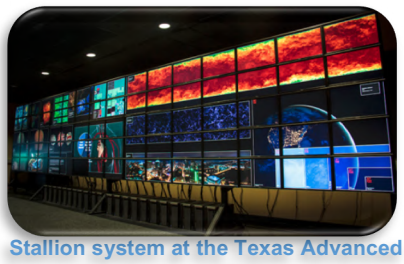
Those fortunate to visit the exhibition “*100 square moons*” a few years ago will understand perfectly the possibilities of combining high resolution and large area. At a distance of 1-2 metres it is possible to appreciate the full splendor of a nearby supernova remnant, but at 20 cm from the pictures one can discern surprising details that intrigue the scientist, and also inspire the artist or any human being with a minimum of curiosity.

Combining tens of high-definition monitors is possible to gather hundreds of millions of pixels over tens of square meters, which allows us to visualize tens of square degrees of sky with a resolution of an arcsecond. For example, an image with a field of view as those in the exhibition “*100 square moons*” (25 square degrees) requires some 600 Megapixel to reach the resolution of 1 arcsecond we typically attain with professional telescopes. This can be displayed over an area of 17.5 m² (7.3m wide x 2.4m high) with 54 (9x6) 4K 32” monitors. Exploring the sky in this fashion would offer a source of inspiration to both researches and the general public. With appropriate software, we could navigate the sky interactively in a new and very different way.

Numerical simulations have been improving their resolution for decades, on par with their relevance for research in astrophysics. Among modern techniques we can mention adaptive mesh refinement, and simulation sequencies, for example in cosmology, where an initial calculation with limited resolution over a vast volume (Gpc) is performed, and later smaller regions are re-simulated (Mpc) to study finer details.

Having means for the interactive visualization of numerical simulations, preserving a wide range of scales, and offering researchers the possibility to resolve fine structures by simply getting close to the screen, can be critical to acquire intuition about the physics of the simulated phenomena.

The most advanced centres in supercomputing, and many research institutes, such as the Texas Advanced Computing Center, the University of California, or the Argonne National Lab, have developed visualization laboratories to support their researchers. Various software packages have been developed for this purpose. For the IAC, this is an investment for the long run with multiple benefits: from research to outreach, not to mention the impact on the media triggered by this type of facilities.



Stallion system at the Texas Advanced Computing Center (328 Megapixels)

We believe that in the following years the IAC should invest in human and material resources in this direction. The investment must be modest in the beginning, but serious enough to permit the acquisition of the necessary basic experience over the next four years.

Strategic Objective:	1,2,3	Related Strategy:	D, G, H	Responsible Unit:	IACTEC

Action 15. SPECIFIC CUTTING-EDGE TECHNOLOGIES: Cryogenic systems

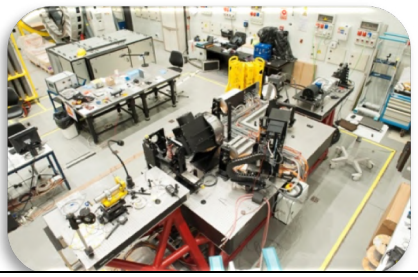
Cryogenic cooling plays an important role in the development of astronomical instrumentation for the present period.

To this end, the main objective pursued in this period is to

- To develop ultra-low vibration cryostats, such as our **Liquid Nitrogen Flow Cryostats**. The LNFC is an advanced liquid nitrogen flow cryostat that uses many unique features, such as the heat exchanger and flow transfer line, to achieve efficiency and ultra-low vibration levels.
- To gain solid experience with low-vibration cryocoolers, such as single-stage **Stirling or Pulse Tube coolers**, which are capable of providing significant cooling power at an operating temperature of around 50K (for IR detection).
- To significantly minimise the already low level of exported vibration generated by conventional cryocoolers (Stirling and Pulse Tube), it is necessary to develop vibration-free technologies for the next generation of instruments. To achieve this performance, cryocoolers based on **Sorption or Turbo-Brayton** can be proposed. The Sorption cooler offers the advantage of being free from the vibration source of the mechanism, while the Turbo-Brayton rejects exported vibration well above the critical bandwidth.
- In addition, it is necessary to develop cryostats that have the advantage of being easily bakeable at 200 ºC. For this purpose, the cold head has to be removed quickly from the interface without breaking the vacuum.

In the Visible range, (nominal temperature -80ºC - 110ºC) it is necessary to gain experience with **Solid-State Peltier coolers, or Thermo-Electric Converters (TECs).**

Strategic Objective:	1,2,3	Related Strategy:	D, G, H	Responsible Unit:	Instrumentation Division



Action 16. SPECIFIC *CUTTING-EDGE TECHNOLOGIES: high spatial resolution*

The aim of this activity is to increase and promote leadership in the development of instrumentation of high spatial resolution. Most of the work associated with this action consists in the development of state-of-the-art astronomical instrumentation for large telescopes, to continue gaining expertise and to allow producing new science in this field..

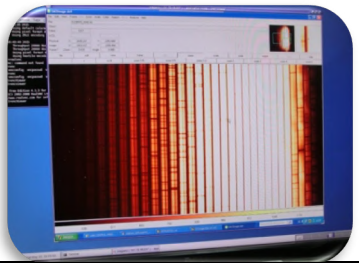
The main instruments to be developed in the framework of this action are the following:

- GTCAO – The Adaptive Optics system for GTC. The integration and commissioning of GTCAO in GTC is expected in 2022.
- Infrared Imager for GTCAO – The first science instrument to perform high spatial resolution observations with GTC. The integration and commissioning of the Infrared Imager in GTC is expected in 2022.
- LGS – the Laser Guide Star Facility for GTC, to extend the use of GTCAO and enable high spatial resolution science in any field of the sky. The integration and commissioning of LGS in GTC is expected in 2024.
- FRIDA - a high-spatial resolution and near infrared integral field spectrograph with imaging capabilities for GTC. This is the instrument that will exploit all the capabilities of GTCAO. The integration and commissioning of FRIDA in GTC is expected in 2024.

- GTCGLAO – The GTCAO upgrade to Ground Layer Adaptive Optics will allow high spatial resolution observations in a large corrected field of view. The integration and commissioning of GTCGLAO in GTC is expected in 2025.
- MCAO Demonstrator for EST – The laboratory demonstrator of the Multi-Conjugate Adaptive Optics for the EST is a fundamental step to validate and complete the design of the MCAO system of EST. The first MCAO results in laboratory of the EST MCAO demonstrator are expected in 2022.
- LARES – Within its Optics Department, the IAC is consolidating the Laboratory of High Spatial and Spectral Resolution. LARES is developing a test bench to compare the performance of three types of wavefront sensors in different real scenarios. The first results are expected for 2022.
- Binary AO – In the framework of LARES, the next step is the demonstration of Binary Adaptive Optics, with the use of Spatial Light Modulators and other new technologies to control phase and amplitude of the wavefront and enhance the performance of AO systems. The first demonstration is expected for 2024.
- Machine Learning in AO – The use of Neural Networks in AO is starting to develop, and the plan is to apply them to complex AO configurations, like MCAO, both for night time and solar AO.

Some of these instruments are also of special interest for other actions under this Strategic Plan, where high spatial resolution is a key technology:
EST – Design and technology developments

Strategic Objective:	**1,2,3**	Related Strategy:	**D, G, H**	Responsible Unit:	**Instrumentation Division**



Action 17. SPECIFIC CUTTING-EDGE TECHNOLOGIES: high spectral resolution

The aim of this activity is to increase and promote leadership in the development of instrumentation at high spectral resolution. Most of the work associated with this action consists in the development of state-of-the-art astronomical instrumentation for large telescopes, to continue gaining expertise and to allow producing new science in this field..

The main instruments to be developed in the framework of this action are the following:

- HIRES – High Resolution Echelle Spectrometer for the second generation of instrument of the European Extremely Large Telescope (ELT). The phase B of the project is expected to start in 2022.
- HARPS3 – High Resolution Echelle Spectrograph for the 2.5m Isaac Newton Telescope in the Roque de Los Muchachos Observatory. The first light of the instrument is expected during the second quarter of 2023.
- NIRPS – Ultra-stable High Resolution Spectrograph for the 3.6m Telescope of La Silla Observatory (European Southern Observatory, Chile). The first light is expected during the last quarter of 2021.
- Chinese High Resolution Spectrograph for GTC. An ultra-stable high dispersion visible spectrograph will be built by NAOC with scientific and technical participation of the IAC. First light expected 2025.

Some of these instruments are also of special interest for other actions under this Strategic Plan, where high spectral resolution is a key technology:

- EST – Design and technology developments

On-going activities:

- To carry out this activity institutional support from the IAC is needed to cover infrastructure maintenance (labs, workshops), support from the IAC's computer services, and support from the administrative management (specially for the purchasing procedures).
- In terms of manpower, more flexibility in contracts and long-term stable contracts are needed to attend the engineering activities agreed with international consortiums. Also the production activities require at least the recruitment of one technician per year for the duration of the plan.

A very significant amount of external funding is needed to guarantee the participation of the IAC in all these projects, as a member of international consortia. There are funds approved up to 2022 for HARPS3, and additional funding will be requested during the period 2022-2025.

Strategic Objective:	**1,2,3**	Related Strategy:	**D, G, H**	Responsible Unit:	**Instrumentation Division**

Action 18. SPECIFIC CUTTING-EDGE TECHNOLOGIES: Free-Space Optical Communications

Optical communications in space has been identified as a key technology for present and future information transmission between satellites and with Earth. It provides a number of advantages with respect to high frequency radio, but its outstanding role in cryptography is the feature which will drive the field in the coming years, and is the one identified to be pursued strategically at IAC: The capability of providing intrinsically secure communications based in laws of quantum mechanics and quantum optics.

- The main objective sought in this period is to put together a team of engineers working coordinately in the field of Free-space optical communications (FSOC), both classical and quantum, paying special attention to the aspects where more relevant contributions can be made, like the design and operation of ground stations and the use of adaptive optics to compensate the atmospheric turbulence
- A quantum optical laboratory will be installed at the IACTEC building, where the experiments will be integrated and tested, as a previous step to their installation either as payloads or at the OGS telescope. General purpose optical equipment, laser sources, single photon sources and detectors, high bandwidth oscilloscopes, wavemeters,etc. will be available.
- The previous work existing towards the commonalities between the FSOC and the AO will be continued and pushed forward, specifically in the aspect of laser launching which pre-correction of the atmospheric turbulence, which was pioneered for the first time ever at IAC.
- The commercial vocation and the clear philosophy of collaborative work with other groups, both public and privately owned, will be present as one of the strategic targets of this group, including the participation in national or international associations. The continuation and reinforcement of the activities related with ESA will also be a strategic objective.

Key factors:

- experience of IAC in projects related to FSOC since 1990 (OGS, SILEX, AIM,...)

- access to ESA's OGS telescope, located in Observatorio del Teide
- Closely linked activity with Adaptive Optics, originated in the need of overturning the negative effects of the atmospheric turbulence.
- Leverage the pioneering of the uplink correction of the laser being launched, which was achieved for the first time ever in june 2019 by our group.
- To identify and include a commercial vocation in the developments, which eventually may end up with the creation of spin-offs around IACTEC

Milestones

- 2022: Building the Quantum Optical Communications Laboratory at IACTEC, and achieving a quantum communication indoors.
- 2023: Installing a quantum communications between islands
- 2024: Building a quantum optical ground station and receiving a quantum communication from a satellite

2025: Establishing a quantum key distribution grid between islands

Strategic Objective:	**1,2,3**	Related Strategy:	**D, G, H**	Responsible Unit:	**Instrumentation Division**

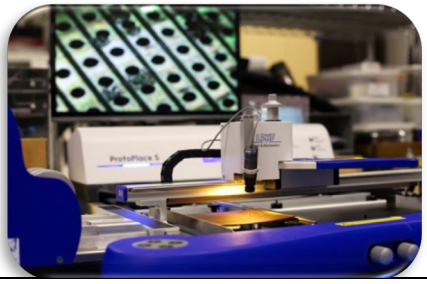
Action 19. SPECIFIC CUTTING-EDGE TECHNOLOGIES: New Detectors

One of the main activities of the technology division is all the activity related with detectors. Indeed, LISA, the laboratory of image and sensors for astronomy, is a key infrastructure at the IAC to characterize and test the potential detectors that will be used in the telescopes and their instruments. The control electronic and the technology-based of the detectors are constantly in progress. Thus, as a specific facility devoted to detectors, it is crucial that new detectors will be considered strategically as future sensors for the instruments..

- LISA laboratory is constantly in progress. Thus, one of their goals is to study and incorporate new technological-based detectors and sensors. The goal for this period is to study and acquire different technologies of detectors that are not currently under control and knowledge in the framework of LISA. These technologies must be the most advanced ones in their fields that could establish a new paradigm in the future for astronomical detectors.
- Due to the previous experience and equipment availability, these new detectors will be tested at the current LISA facilities. Some of them will require additional equipment to be operated, such as specific dedicated cryostat or new light sources.
- LISA will also undertake during this period the supply of detectors and their acquisition systems to astrophysical instruments requiring them, as part of the collaborative effort provided by IAC to the consortium. Specifically OSIRIS, EMIR, FRIDA and GTC-AO will be equipped with detectors tested at LISA, which will also be responsible for the detector related work package.

Regarding the extension of LISA capabilities to new detectors, some of the current technologies that have been identified as potential candidates are MKIDs and APDs, due to their extremely high sensitivity and versatility to be designed for different astronomical applications. The objective for this period is to put together a complete system for MKIDs testing, including a superconducting temperature cryostat, and a data acquisition system in the microwave range for their readout. APDs and single photon detectors will also be tested.

Strategic Objective:	1,2,3	Related Strategy:	D, G, H	Responsible Unit:	Instrumentation Division



Action 20. SPECIFIC CUTTING-EDGE TECHNOLOGIES: Microelectronics

The aim of this activity is to increase and promote leadership in the development of microelectronics for astrophysical instrumentation.

This action is the natural continuation of the "Equipamiento Microelectrónica IAC, EMIAC" project from the national programme for infrastructure that is still in execution (2020-2021). The objective of this project is to provide the Electronics Department in the Technology Division of the Instituto de Astrofísica de Canarias (IAC) with the capability to design and verify integrated circuits with different modern and conventional technologies. The obtained budget includes the costs of covering the necessary equipment, instruments, software, technologies and also of prototyping a chip. This new capability, to design and verify integrated circuits with different technologies, can be applied to a large quantity of research projects in astrophysics. Many instruments may profit from the use of a full or semi-full custom electronics design that is not commercial or is very expensive, and they can be an adequate candidate for this kind of prototyping with modern technologies. In particular, it is possible to find suitable examples for developing microelectronics for astrophysical instrumentation in integrated photonics, optical communications, adaptive optics, space projects, microwaves, experimental and commercial detectors and their readout and processing interfaces.

Based on these objectives, a polarimetry interface based on accumulation in wells was the first application of microelectronics to astrophysical instrumentation that was identified at the IAC. Preliminary results, thanks to having had a summer intern during 2020, show that the proposed architecture could improve the current solution, so the intention is to examine it more in-depth through a doctoral thesis (already accepted by the IAC doctorate commission) until reaching the design and implementation of an integrated circuit that contains the proposed polarimetry interface.

The plan for 2022-2025 is to take full advantage of this capability with the development and improvement of astrophysical instrumentation, the participation of the IAC in future national and international projects in which the development of integrated circuits is required and the expansion of collaborations with top research centres that need or can benefit from these capabilities

Key factors: An infrastructure project (EMIAC) for implementing the IC laboratory, including the cost for necessary equipment, instruments, software, technologies and fabrication of the chip has already been accepted.

This capability can be applied to a large quantity of research projects in astrophysics.
Some suitable examples have been detected such as polarimetry, integrated photonics, optical communications, adaptive optics, space projects, microwaves, experimental and commercial detectors and their readout and processing interfaces.

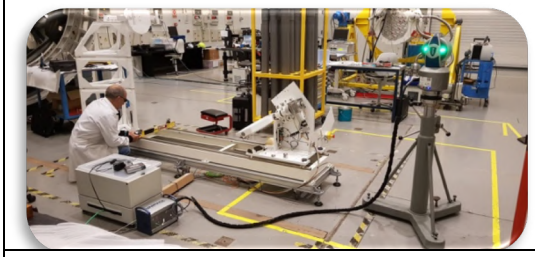
Milestones:

- To implement the IC laboratory.
- To choose the appropriate modern or conventional technology.
- To design and verify the first integrated circuit in the IAC.

- To take full advantage of this capability with the development and improvement of astrophysical instrumentation.
- To participate in future national and international projects in which ICs are required.
- To expand collaborations with research centres that need these capabilities.

Main stakeholders:
IAC, ESA, International and Spanish industrial sectors, collaborators from several research centres.
Additional remarks: This foray into the world of IC will allow us to have access to the most modern and cutting-edge technologies for developing chips including ASICs, Photonics, MEMS and Power Electronics. This will help us to continue being part of the development of the most advanced astrophysical instrumentation.

Strategic Objective:	**1,2,3**	Related Strategy:	**D, G, H**	Responsible Unit:	**Instrumentation Division**



Action 21. Participation in Large Space Missions

The aim of this activity is to increase and ensure the IAC participation in instrumentation and payloads for space missions.

The following missions are considered:

- PLATO is an ESA M3 class mission in the Cosmic Vision 2015-2025. The main objective is to find habitable exoplanets, similar to the Earth, by using different methods that allow planet detection; radius determination; determination of planet masses; determination of accurate stellar masses, radii, and ages; and identification of bright targets. The payload consists of 26 telescopes, and IAC is responsible for power supply units of the main electronic units.

- SUNRISE is a balloon-borne solar observatory dedicated to the investigation of the key processes governing the physics of the magnetic field and the convective plasma flows in the lower solar atmosphere. For the next flight planned for 2022, the post-focus instrumentation is upgraded with new spectro-polarimeters for the near UV (SUSI) and the near-IR (SCIP), and the imaging spectro-polarimeter Tunable Magnetograph (TuMag). To support this mission, the IAC collaborates in the development of the Digital Processing Unit for SCIP and TuMag, as well as a new image sensor for these instruments.

- ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large-survey) was selected as the fourth medium-class mission in ESA's Cosmic Vision programme. It will study what exoplanets are made of, how they formed and how they evolve, by surveying a diverse sample of about 1000 extrasolar planets, simultaneously in visible and infrared wavelengths. It is the first mission dedicated to measuring the chemical composition and thermal structures of hundreds of transiting exoplanets, enabling planetary science far beyond the boundaries of the Solar System.

- LiteBIRD (Lite (Light) satellite for the studies of B-mode polarization and Inflation from cosmic background Radiation Detection) is a planned small space observatory that aims to detect the footprint of the primordial gravitational wave on the cosmic microwave background (CMB) in a form of polarization pattern called B-mode.

- BREAKTHROUGH STARSHOT, which pursues the sending of a sail capable of reaching the nearby star Alpha-Centauri, can use technologies developed at IAC in two fields. On one side, the uplink correction of the high power lasers being use to push the sail to 20% of c, and on the other side, to use extremely deep space optical communications.

Strategic Objective:	1,2,3	Related Strategy:	D, G, H	Responsible Unit:	Instrumentation Division

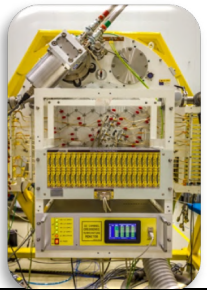
Action 22. Optical/IR Instrumentation

This activity is focused on the development of advanced optical/IR astronomical instrumentation.

The following actions are considered

- EST - Technology developments: Continue the development of new techniques for 2D solar spectro-polarimetry with integral field units on multi-slit image slicers.
- HARMONI: First light integral field spectrograph for the E-ELT
- FRIDA: A high-Spatial resolution and optical/near infrared integral field spectrograph with imaging capabilities for GTC
- GRANCAIN: A high-Spatial resolution near infrared camera for GTCAO
- MIRADAS: a mid-resolution near-infrared multi-object echelle spectrograph for GTC
- HARPS3: A high-resolution optical echelle spectrograph for INT
- HIRES: A high-resolution fiber spectrograph in the optical and near-infrared for the E-ELT.

Strategic Objective:	1,2,3	Related Strategy:	D, G, H	Responsible Unit:	Instrumentation Division



Action 23. MICROWAVE TECHNOLOGIES FOR CMB POLARIZATION AND SPECTROSCOPY

the aim is: i) to conclude the MFI2 for 10-20 GHz imaging using the QUIJOTE telescope; ii) build a new instrument, the Tenerife Microwave Spectrometer (TMS), which will carry out Spectroscopy in the 10 – 20GHz frequency band and will be a prototype for future ground-based and space instruments; iii) participate in the development of a MKIDS based instrument

- Current telescopes at the Teide observatory include: i) the QUIJOTE telescopes (QT-1 and QT-2) and three state of the art instruments to study the CMB polarization: MFI (10-20GHz), TGI (30 GHz) and FGI (40GHz); Ii) KISS, a visiting spectrometer from the University of Grenoble which operates at 90 – 150GHz with MKIDS from QT-1; iii) GroundBIRD, an MKID based polarimeter which operates at 145 and 220 GHz. This also will measure polar signals from the CMB. Future instruments expected throughout 2022 are: i) the LSPE-STRIP instrument which is a polarimeter array operating at 40 and 90 GHz to be installed in its own telescope. This instrument is fruit of a collaboration with University of Milan, INFN and an international team; ii) MFI2, which is an upgraded version of MFI using a digital back-end based on FPGAs, is expected to be finished in 2022.
- All these new instruments are expected to observe through to 2025. The combination of the data from this group of instruments and telescopes will make the Teide observatory one of the most complete CMB observatories in Europe spanning a frequency range from 10-200GHz. QUIJOTE-MFI and MFI2 are the only CMB polarization experiments currently operating in the 10-20GHz band. Their maps will have a clear legacy value for modelling

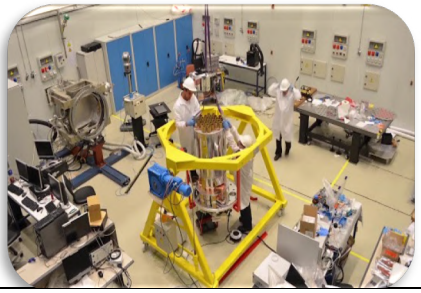
the synchrotron emission in future missions like LiteBIRD (its lowest frequency channel is 34 GHz).

- TMS and MFI2 will be the first CMB instruments at Teide observatory that use FPGA direct acquisition. The knowledge and experience obtained from this new technique of acquisition will be passed on to other projects in the IAC and IACTEC since their use extends to MKIDs and space based acquisitions systems. Each instrument has required individual component specifications well-beyond present commercially available models. Already the IAC has provided an octave bandwidth corrugated conical horn design to meet the TMS requirements. Also the 4K pyramidal load was designed and modelled at the IAC in collaboration with the INAF, Bologna. A collaboration with the UPCT in Cartagena has provided the way forward to implement FPGA direct acquisition for up to 2.5GHz bandwidth. By the start of 2022 there will be a fully operations micro-electronics laboratory capable of microchip design and testing. This is important for the increasing complexity of instrument design. Microchips are foreseen up to 20GHz operation. Also a new higher precision and automated milling machine has been purchased to handle the high volume of microwave circuits needed for the FPGA solution to the backend and to be able to build higher frequency circuits for future instruments.

Milestones

- 2021: First working FPGA based acquisition system
- 2022: First Light of the MFI2 on the QUIJOTE telescope
- 2022: First measurements of MKIDs in the test cryostat
- 2022: First design and measurements of 90-110GHz components
- 2023: First Light of the TMS instrument
- 2023: First Light of the LSPE-STRIP instrument
- 2025: First results published with the TMS and MFI2 instruments

Strategic Objective:	**1,2,3**	Related Strategy:	**D, G, H**	Responsible Unit:	**Instrumentation Division**



Action 24. GENERAL CAPACITIES AND TECHNOLOGY

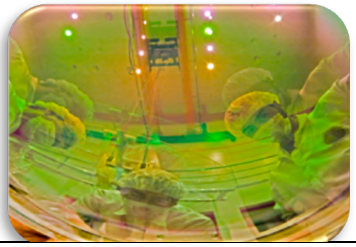
the aim is to improve the IAC technology capabilities, both the facilities and the knowledge level of our personnel,

In particular, the following activities would be implemented during the period 2022-2025:

- Extend the LISA (Laboratory of Imaging and Sensors for Astronomy) from visible/mid IR to the use of superconducting detectors, and offer its capabilities to other institutes in a collaborative approach.
- Improve the existing test and measurement equipment for microwave electronics, and increase the number of people with that know-how at the IAC.
- Continue the developments of FPGA-based control systems, extend this know-how to processing systems in the microwave range, and include the use of multiprocessing-dedicated graphical processors (GPUs) in the building blocks of known technologies.
- To create a Mechatronics Laboratory as a new facility, where models of instruments and telescopes will help developers during design, simulation and verification of control system architectures and strategies. It will be useful at the beginning with the ongoing projects HARMONI, EST, QUIJOTE and NRT,
- Improve the clean room conditions in the AIV Room.
- Install a temperature control system in the CNC machines area to improve their efficiency.
- Improve the capability of the mechanical workshop renovating older machines (some of them have more than 35 years).
- Continue researching to optimize the results of additive manufacturing to achieve a valid application in scientific instrumentation (in particular in instrumentation related to astrophysical research), such as refrigerated mirrors designed with this technique, manufacture of parts that contain different materials, etc …

Create a new line of research on nano-mechanics and its applications in scientific instrumentation looking for companies, institutions or universities that may be interested in this field.

Strategic Objective:	**1,2,3**	Related Strategy:	**D, G, H**	Responsible Unit:	**Instrumentation Division**



Action 25. Development of the Center of Advanced Optics (CSOA)

The aim of this activity is to develop a new technological capability for designing and manufacturing advanced optical elements

The CSOA is conceived with the aim of meeting the demand for quality optical elements as a rising value for the coming decades.

Sectors such as astronomy, where large telescopes demand hundreds of mirrors with complex shapes and rigorous requirements, the space sector with projects covering large clusters of satellites observing the earth or space, the laser industry, where optical components of the highest quality in surface finish and coatings are required, the development of the alternative energy industry, in particular the solar light harvesting industry where a high surface quality of the elements is not required, but has significant needs for special coatings.

The CSOA is a key guarantor in the relevant participation in any project that requires the manufacture of optical elements as it has the necessary capabilities to manufacture them and therefore ensure a scientific and technological return on the investment.

The IAC's strategy in this area, articulated through the CSOA, aims to:

- Meet the demand for quality optical elements in key RTD & Innovation sectors.
- To manufacture optical elements with complex shapes and demanding requirements in terms of shape and surface roughness, filters, dichroics and optical/infrared components for satellite payloads.
- Design and development of sensors.
- Development of new technologies for ultra-light mirrors (additive manufacturing and replication techniques).
- Promotion of digital optical communications.
- Technology transfer to the medical sector.
- Advanced training and entrepreneurship in the optics sector.

In particular, the following activities would be implemented during the period 2022-2025

- Implementation of the Center of Advanced Optics
- Manufacture of segments for NRT Telescope.
- Manufacture of optical elements for NRT instrumentation
- Manufacture of optical elements for IAC satellites.
- Development of new techniques for mirror manufacturing using additive manufacturing.
- Development of mirror manufacturing using replication techniques
- Lightening of mirrors for satellites
- Development of freeform optics
- Improvements in optical metrology

Strategic Objective:	**1,2,3**	Related Strategy:	**D, G, H**	Responsible Unit:	**IACTEC / Instrumentation Division**

TRAINING OF RESEARCHERS AND ENGINEERS

Action 26: Master and Doctorate. Summer programmes and schools.

The aim of this activity is to support the Master and Doctorate in Astrophysics together with University of La Laguna, as well as the continuity of the Summer fellowships programme and the Canary Islands Winter School of Astrophysics.

We aim to give in-depth training to the new generations of astrophysicists that will use the exciting new possibilities in instrumentation and computer modelling.

- Master in Astrophysics: support the studies in the ULL at this level.
- Doctorate: The objective is to appoint nine new PhD students per year funded directly by the IAC or by the Severo Ochoa Centre of Excellence grant. Additionally, at least 3 more PhD students per year are expected from Spanish, UE projects and La Caixa Foundation
- Summer fellowship research programme: Six students per year will be supported for the next four years period.
- Summer fellowship technology development programme: six students per year are planned for the next four years period.
- Canary Islands Winter School: The Canary Islands Winter School in Astrophysics will continue being supported by the IAC as one of its main programs.
- Training of end-of-the-career students of the Universidad de La Laguna, Universidad de Las Palmas de Gran Canaria, and Universities from mainland Spain.
- Training of students through curricular practices in technical, communication and administrative issues.

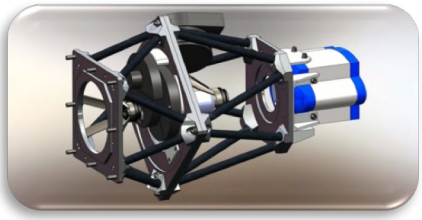
Strategic Objective:	**1,2**	Related Strategy:	**E**	Responsible Unit:	**Graduate Division**

Action 27: Training through research

Every year some 20 postdocs and around 10-15 PhD students join the IAC. PhD studentships last for 3 years, while the typical postdoctoral position last for about 2-3 years. Each of the Research lines of the IAC Program provides training on research-related skills, including hands-on observations using the largest telescopes and space missions, data reduction, analysis, and/or physical interpretation.

Research Post-docs, through their supervisor or direct group leader, are trained in state-of-the-art research techniques including both data analysis and modelling efforts. Research Fellows are also trained in science management through the possibility of leading small projects or large internal projects for senior postdocs. Supervision of more junior research staff and/or organizing workshops and conferences, are among other possibilities to further complement their training as professional researchers.

Strategic Objective:	**1,2**	Related Strategy:	**E**	Responsible Unit:	**Research Division**



Action 28: Master degree: Design of Instrumentation for Astrophysics and Space

The aim of this activity is to support the creation of a new Master on design of instrumentation for Astrophysics and Space. This is a joint effort of University of La Laguna, and the Graduate and Instrumentation Divisions of the IAC.

We aim to give in-depth training to the new generations of scientists and engineers to design, plan, carry out, and verify cutting-edge technology for Astrophysics and Space Sciences.

The new master will cover the following topics:

- Optical design.
- Mechanical design.
- Sensor, control and processing electronics.
- Control software.
- Integration and verification of instruments.
- Systems engineer.

Being a blended training where teaching is designed for virtual classes in video or streaming mode, software tools will be necessary within a virtual classroom platform, which are currently available on the website of the University of La Laguna.

The IAC has the necessary infrastructures for its correct development. Thus, it has optical, mechanical and electronic laboratories, integration rooms of instruments, and mechanics and electronics workshops. In addition, it has multiple design tools (optical, mechanical and electronic software), integration and verification systems both optical, electronic and mechanical.

Strategic Objective:	**1,2,3**	Related Strategy:	**D, G, H**	Responsible Unit:	**Graduate & Technology Divisions**

Action 29: Design and development of advanced technologies in collaboration with industry

The new technology centre IACTEC will be focused on technologies for astrophysics (large telescopes), space (microsatellites and optical communications), Optics and Biomedicine.

This initiative aims to develop technological potential in astrophysics, space and related areas of scientific instrumentation and support the generation of a new and innovative business framework in the Canary Islands.

Since August 2020 the new IACTEC building is in operation at the Scientific and Technological Park of La Laguna, and it is being progressively equipped with the infrastructure obtained through the Science Ministry funds and also the EU funds.

The initial technological programs (Large Telescopes, Microsatellites and BioMedical Technology) will continue its activity, and new programs (Optical Communications with Space, the Centre for Advanced Optics Systems) have just started and will be supported through the next 4 years.

IACTEC will foster the following sub-actions:

1. Large Telescope Programmes. IACTEC helps to boost the leading role achieved the Science Industry of Spain, specializing in large telescopes, strengthening its presence in large-scale projects in which Spain collaborates with, and in some cases leads, international consortia. For 2022-2025, major effort will be focused on the implementation of the design, preparatory and constructions phases of major research infrastructures to be located at the Observatorios de Canarias : CTA, EST, NRT, ASTRI, MiniELF and ultimately ELF.
2. Space Programme. IACTEC will boost innovation and development relating to the payload of micro- and nano-satellites, a growing sector with great impact on areas such as astronomy, communications, defence and security, environmental management, etc. Our initial focus will be on observations of the Earth and the development of small space missions for astronomy (20 cm class telescopes) with a view to develop further our technological capabilities for application to space observational projects with larger satellites. IACTEC will also host the laboratory for Optical Communications (described in Action 18).
3. Biomedical applications: Development of electro-optical devices implementing technology used in Astrophysics for medical technology.
4. Centre for Advanced Optical Systems. A major facility to be located in the IACTEC building is already described in Action 25.

Transversal sub-actions:

1. Consolidation of the project teams: it is expected to sustain a team of up to 16 engineers from 2021 to 2024 thanks to the “Capacitación” programme of the Cabildo de Tenerife. The engineers that complete 4 years in the programme, will be absorbed by initiatives that they have to build during their stay (creating their own company, or joining a new project with external funding they help rising). A total of 10 engineers are expected to succeed this transition and continue their stay at IACTEC after the Capacitation programme by 2024.
2. Laboratory for Visualization of Technical and Scientific Data,
3. Research on new ways of transference of technology to the private sector will be continued.

Strategic Objective:	**1,2,3**	Related Strategy:	**D, F, G**	Responsible Unit:	**IACTEC**

Action 30: New infrastructures: Support to IACTEC and CATELP

two new major infrastructures will be produced and operated

- CATELP. This is an initiative with the Cabildo de La Palma, to be constructed at sea-level, close to the airport of la Palma. The current facilities of the IAC at CALP would be moved to CATELP. CATELP is still in process of formalization and awaiting decisions to enter construction. The building with capacity for 400 people is already designed and the duration of the construction phase is estimated at 3 years.
- The IACTEC building is already operative at the Science and Technology Park of Tenerife. The goal is to cover operation costs and to equip the laboratories for Space technologies (microsatellite payloads and optical communications) and the Centre for Advanced Optical Systems.

It is crucial to be prepared to face the new operating costs that these infrastructures will mean for the IAC. In many cases operating expenses will be shared with other institutions, and in some cases the operating costs will be provided by the corresponding collaborative projects to be carried out there.

Strategic Objective:	**1,2,3**	Related Strategy:	**B, G, H**	Responsible Unit:	**General Administration**

Action 31: Public Outreach, Communication Media and Corporate Image

The communication of the scientific and technical results generated in the IAC and in the Observatories of the Canary Islands through all possible ways and resources, both with the traditional press releases, annual reports, brochures, web, social networks, blogs, etc.

We highlight the following lines of action:

1. National and international promotion of the Observatories of the Canary Islands thanks to the collaboration of all the IUs of the telescopes in Tenerife and La Palma.
2. Consolidation of relationships with the Canarian society, giving value to the "canary sky" as unique heritage in the world.
3. Promotion of scientific vocations and promotion of activities related to the friends of astronomy, with a special effort in the empowerment of the presence of women both in the world of professional and amateur astronomy.
4. Training of communicators and journalists specialized in science and technology, teaching professors and own staff.
5. Development of outreach projects aimed at the educational community as well as transversal projects in which literature, art, music, cinema and astronomy are merged. Cooperation with the Science Museum (Tenerife) and the Visitor Centre (la Palma).
6. Institutional support for the organization of special events such as, for example, those associated with milestones of new infrastructures or anniversaries of the current ones.
7. Generation of international networks for the outreach of astronomy to constitute them as consolidated platforms of good practices, channel of dissemination of results and products.
8. Search for funding for IAC projects from public and private sources, through grants, agreements, sponsorships, patronage, donations, etc.

To secure the success of the proposed activities we will consider:

- The fluid interaction with RTD personnel of our institution as well as those belonging to related sectors, especially public institutions and financing entities.
- Close contact with all entities with telescopes in our observatories, and large networks and organizations with outreach programs (IAU, ESO, ESA, etc.)
- Consolidate groups of users of future visitor centres and empower potential consumers of scientific culture.
- Maintain a close collaboration with the Educational Community (both with teachers and General Directorates of Educational Innovation) for the joint stimulation of projects.
- Encourage the relationships with those actors / agents integrated in transversal projects related to people with disabilities, as well as the integration of women in science.

Strategic Objective:	**1,2,3**	Related Strategy:	**C, F, G**	Responsible Unit:	**UC3**

Action 32: Towards a complete Digital Transformation for an efficient management

The excellence of an organization, as to the accomplishment of its mission and objectives and its productive activity, is strongly conditioned by the efficiency of its management system. The IAC is aware of the importance of updating and adapting its management model to the main principles of digital administration, across IAC units, with project-oriented perspective.

In line with the provisions set by the State General Administration, the IAC Digital Transformation Action Plan has been developed and in force, defining a set of activities to be implemented in the period 2021-2023, encompassed by the IAC Strategic Plan, and monitored during the second period, 2024-2025.

The planned actions will address issues related to document management, the implementation of tools to improve the provision of digital services, basic training in e-administration, or the implementation of the digital workplace, a necessary step towards real telework, among others.

The Digital Transformation process involves many changes that will be progressively incorporated over the next few years. This first approach will address the fundamental aspects that will enable us to comply with the necessary measures, trying to provide the IAC with practical and useful solutions.

The project portfolio of our Digital Transformation Action Plan includes: (1) updating and improvement of our management procedures catalogue; (2) development of software solutions to manage internal processes; (3) document management; (4) the integration of standard tools with IAC processes; (5) training; and (6) indicators definitions for further follow-up.

Software developed, good practice guides, as well as lessons learned should be generalized, as far as possible, in order to be exported to companies with similar needs and thus contribute to the social and economic development of our environment.

The aforementioned specific activities will be mainly executed during the first two years of the Strategic Plan, and the second two years will be necessary for the appropriate follow-up, resolution of incidents and the consolidation of the new digital model. A total budget of 240 kEUR, for investments (40 kEUR) and services (200 kEUR) is assigned to this e-Plan, as well as 2 FTE, during the 4 year period.

In addition, we will also need to make a greater effort in new IT equipment, so that this transition to digital management is possible and under current technological standards.

In that sense, we need to adapt our current Enterprise Resource Planning (ERP) software (SAP).This ERP software supports our main management processes: Procurement, traveling, financial, project and human resources. Following investment actions are needed:

- Configure Business Partner (BP) Module. This project is a previous step to adapt suppliers and personal database to new SAP supported version.
- Migration to SAP HANA data base. We need to acquire powerful computer servers and migrate all data base to new SAP technology.
- Migration from SAP to S/4 HANA. This final project will migrate procurement, traveling, financial, project and human resources management modules as well as local programs to last updated SAP version.

We plan to assign to this software and hardware update a budget of 308 kEUR. 3 FTE will be also dedicated to this IT adaptation.

In total, a budget of 548 kEUR and 5 FTE during a period of 4 years.

Strategic Objective:	**1,2,3**	Related Strategy:	**H**	Responsible Unit:	**General Administration**

Action 33: Corporate Social Responsibility

Social responsibility, understood as an active and voluntary contribution from the organizations to promote social, economic and environmental improvement, acquires special relevance for public entities. The aim of this action is to work towards greater social responsibility in our day-to-day activity: environment, labour policies and fair governance.

During recent years, the IAC has implemented specific actions in order to introduce improvements in this direction. However, it is worth mentioning here that social responsibility is something inherent to the IAC's own activity: fair selection processes, studies on socio-economic impact related to the construction and exploitation of telescope facilities, our activity at the observatories (areas under the highest protection), activities on gender issues, etc.

Under the new Strategic Plan, we propose to undertake new actions and to consolidate those achievements obtained in the past. In some cases, these actions have been already developed at a small scale as prototypes or pilot actions, and some are implemented and need just continuity and reinforcement:

ENVIRONMENT:

- Consumption of water, paper and other raw materials.
- The use of renewable energies, particularly, solar photovoltaic.
- Continuous replacement of our fleet vehicles for electric/hybrid ones.
- Air conditioning systems based on solar energy.
- Implementation of a quality system for environmental monitoring at the IAC HQs and Observatories.

RIGHTS AND LABOUR POLICIES:

- Gender Equality Plan (ongoing). The III Gender Equality Plan has been recently approved and it will run during the first years of this new Strategic Plan.
- A new structure for permanent and temporary positions at the IAC (described and to be developed under a later action).
- Collective negotiation.
- Health and safety at work.
- Performance evaluation following guidelines from the State Administration.

FAIR GOVERNANCE:

- Code of Conduct.
- Transparency (already in place, but to be improved during the Strategic Plan).
- Communication.
- Quality.

There are other issues to be addressed to become fully *Socially Responsible*. We will address all of them, but special efforts will be made on those listed above.

No additional financial resources, apart from those provided by our consecutive Annual Plans or by specific projects supported with external funds, are needed to move forward in this direction. The IAC Directorate and departments/units mainly involved here are well aware about the importance of Corporate Social Responsibility.

Strategic Objective:	**1,2,3**	Related Strategy:	**H**	Responsible Unit:	**General Administration**

Action 34: Private Sponsorship

The IAC meets conditions, valuable assets and critical mass so as to be able to attract private investment, especially for those activities of larger visibility and international impact. The aim of this action is to establish a strategy to attract and to keep private funding (major international companies and local partners) to undertake RTD projects.

There is no doubt that private sponsorship in support of Astronomy research centres is a widespread practice at the United States, though less so in Europe, and very marginal in Spain. In many cases we assume this sponsorship will probably not be interested on the core activity we want to promote, but on those products or sub-products that could emerge in parallel to it, the potential impact in media, technology transfer to other sectors, related cultural activities, etc.

During the previous Strategic Plan we defined the activities and main lines of potential interest for the private sector. We launched the IAC Patronage and Sponsorship Programme, under the name of "Amigos del IAC" (IAC Friends). Different activities are proposed to recognise sponsorship as a complimentary return, in majority of cases.

The objectives of "Amigos del IAC" are:
- To support exploration and discovery in key areas of astrophysics, in synergy with technological developments in advanced instrumentation.
- To strengthen the international projection of the Canarian Observatories in order to optimise the scientific and technical exploitation of the sky over the Islands.
- To increase the quality and impact of the training of doctoral students and doctors, consolidating the IAC as a pole of attraction for young talent.

Several modalities of collaboration are envisaged. Information on Tax Incentives is provided, as well as other relevant information on sponsorship. During the new Strategic Plan we propose to expand our communicating activities in order to increase the number of IAC Friends. https://www.iac.es/en/iac-friends

Strategic Objective:	**1,2,3**	Related Strategy:	**H**	Responsible Unit:	**Direction**

Action 35: Human Resources

Reorganization and consistency with international standards. The most important human resources challenges under the new Strategic Plan are the updating of the Labour Staff Convention, and the implementation of the digital workplace, therefore teleworking. Other support actions on HHRR will be also implemented.

Three actions are envisaged under this activity:

(1) To adapt the current structure of our support staff in accordance to the IAC Statutes and present needs.

The current labour structure of the IAC was defined more than 20 years ago to support the RTD activities of the IAC and its Observatories. However, we need to adapt ourselves to the new situation, new international communities and needs at the Observatories, a considerable increase of our activity and diversification, new specializations, techniques and equipment, outsourcing of services, e-Administration, telework, etc.

Ensuring a proper career for the staff is also of vital importance to support its continuity, motivation and the maximum possible return of the knowledge generated by our own activity.

At the beginning of 2022 we expect to start with the modification of our current own General employment agreement, in force since 2004, to integrate our staff into the Fourth Unique Convention of the General State Administration. This integration process will not be easy: a total of 57 professional categories, among technical and administrative staff, will have to be integrated into a maximum of 14; we will need to guarantee a professional career for our staff under the new agreement; it will be a must to adapt and to approximate the current benefits to those actually existing under the new model; etc. During the previous Strategic Plan a deep analysis of our current situation was conducted. The result of this analysis is a major key-stone to pave the way towards the new Unique Convention. This will be a long process, but necessary.

(2) To define and implement a new model to attract young/senior researchers and engineers more in consistency with international standards and under competitive conditions.

Strictly following the Spanish Law for Science and Technology, but taking advantage of the maximum possible flexibility, as well as to value the opportunities of the IAC and its privileged position for astrophysical research and even the quality of life enabled by the Canary Islands, it is necessary to improve the working conditions and benefits to become competitive in the attraction of first-class researchers and highly skilled engineers.

(3) A well-balanced distribution of the IAC staff.

As already explained throughout this document, the ratio at the IAC among researchers, technical and administrative staff is 1:1,36;0,32 (2020). In accordance with standards commonly accepted for centres similar to the IAC, this ratio should be at the range of 1:2:0,5. In the case of management staff, this imbalance implies that we had to increase our administrative workforce by 50%, to move from the current 44 workers up to 68. This situation is being partially alleviated by training contracts, but they are not a stable solution, A decisive action in this direction is indispensable to maintain the excellence of our research and technological capacity. A similar situation occurs with technological staff. However, in this case, temporary contracts can provide better long-term solutions on current needs.

During the last years, especially due to the financial crisis, the IAC has not been allowed to replace the support staff at the rate needed, and some efforts to reverse the current situation are a must.

Within the framework of this Plan we aim to incorporate 1 administrative permanent position per year, totalling 4 administrative by the end of the four-year period.

Strategic Objective:	**1,2,3**	Related Strategy:	**H**	Responsible Unit:	**General Administration**

Action 36: Improving remote working

Reorganization and consistency with international standards.

Digital workplace and teleworking. Updating the IAC working model.

COVID-19 took the society to change the scheme in a number of aspects. At the public Institutions as the IAC, teleworking was implemented and a number of protocols were designed to assure its correct functioning. The result in our case has been very positive; the observatories remained open even during the confinement - thanks to the remote operation and the help of people at the mountain and management services that were also in continuous operation.

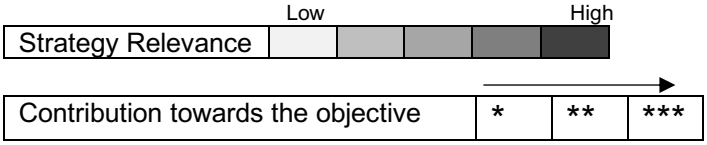
The productivity of the institute remained high and the problems mainly came due to the limitation on the mobility of services and supplies with other parties, who suffered the crisis severely and therefore were not always able to keep their compromises.

During this Strategic Plan we will propose to the IAC Governing Board a specific model for the IAC, in accordance with national regulations, some pilot experiences in different areas and units, starting from the Research, Administration and other Supporting Units, not affected in principle by fundamental needs of laboratories or equipment, or continuous on-site work; and to define and implement the digital workplace, as a key and fundamental piece when producing and leading research and technology of wordwide relevance. IT actions are also included under action 32 to support this specific action of teleworking.

Strategic Objective:	**1,2,3**	Related Strategy:	**H**	Responsible Unit:	**General Administration**

SUMMARY
Objectives, strategies and actions

ACTION	STRATEGY								OBJECTIVE		
	A	B	C	D	E	F	G	H	1	2	3
1	✓		✓		✓				***	*	*
2	✓		✓		✓				***	*	*
3	✓		✓		✓				***	*	*
4	✓		✓		✓				***	*	*
5	✓		✓		✓				***	*	*
6		✓	✓	✓					**	***	*
7		✓								***	
8				✓			✓		*	*	**
9				✓			✓		*	*	**
10				✓			✓		*	*	**
11				✓			✓		*	*	**
12				✓			✓		*	*	**
13					✓				**		**
14					✓				**		**
15			✓			✓	✓		*	**	***
16				✓			✓	✓	*	**	***
17				✓			✓	✓	***	*	*
18				✓			✓	✓	*	*	*
19				✓			✓	✓	*	*	*
20				✓			✓	✓	*	*	***



ACTION	STRATEGY								OBJECTIVE		
	A	B	C	D	E	F	G	H	1	2	3
21				✓			✓	✓	***	*	*
22				✓			✓	✓	***	*	*
23				✓			✓	✓	***	*	*
24				✓			✓	✓	***	*	*
25				✓			✓	✓	***	*	*
26				✓					**	***	*
27		✓								***	
28				✓			✓		*	*	**
29				✓			✓		*	*	**
30				✓			✓		*	*	**
31			✓			✓	✓		*	*	**
32								✓	*	*	**
33								✓	**		**
34								✓	**		**
35								✓	*	**	***
36								✓			

Strategy Relevance					
Contribution towards the objective	*	**	***		

3.4 Resource Strategy

Financial resources needed to implement the IAC Strategic Plan for the period 2022–2025 come primarily from two different sources national and regional budget (approved by the respective parliaments) and external funding:

1. The Spanish National Administration (Administración General del Estado, AGE) and the Canary Islands' Regional Government (CAC), provide the main contributions to the IAC's annual budget. These contributions mainly cover permanent personnel cost (approx. 11-12 M€/year) and running costs (approx. 5-6 M€/year for maintenance, operations, investments and renovations). The participation in the running costs of CTAO and ING (0.8 M€ assumed by the IAC on behalf of Spain) plus the mandatory co-funding (15%) of the existing FEDER supported programmes (of order 1-2 M€/year) leads to a minimum required budget of 18 M€ in year 2022, 19 M€ in year 2023 and 20 M€ in subsequent years of this Plan.

2. External funding obtained under competitive calls, contracts, and other incomes, to carry out research and technology programmes, as well as to train new researchers and technicians; around 4 M€/year on average during the last years (State Plan for Research, EU grants, Regional Gov. Research programmes). Additionally, and related to the operation of the *Observatorios de Cana*rias, another 2 M€/year are provided by the User Institutions and managed by the IAC. During the coming years, due to the participation of the IAC in some specific Large Institutional Projects (CTA, EST, NRT, IACTEC) additional external funding of around 14-15 M€/year (average value from FEDER supported programmes) is expected. So, the total level of External Funds to be managed by the IAC during the 2022-2025 period will be in the range of 20-21 M€/year.

Here, we present a plan to maintain the level of internal funding that IAC has recently achieved while complementary actions will require additional budget for successive years to fund the challenges described in this Strategic Plan.

3.4.1. Human Resources

The following table summarizes the human resources plan for the coming four years.

Evolution and forecast of IAC's Human Resources 2018 – 2025

Group	Profile	2018	2019	2020	2021	2022	2023	2024	2025
Researchers	Researcher – permanent staff	37	37	37	37	40	43	44	44
	Researchers – temporary contracts	69	69	71	71	71	71	71	71
	Researcher – ULL & CSIC staff	24	25	27	27	27	27	27	27
	Technical Specialists - Technicians	0	0	2	2	4	5	6	7
PhD students	PhD students - IAC	53	54	55	55	55	55	55	55
Technical staff	Engineers – Technology Developments – permanent staff	34	33	42	42	44	46	47	48
	Engineers – Technology Developments – temporary contracts	24	27	27	30	32	32	34	35
	Engineers – IACTec – temporary (EST, CTA, NRT)	22	29	30	32	34	36	38	40
	Engineers – IT services	13	13	13	13	13	13	13	13
	Engineers - others	17	18	19	21	22	22	23	24
	Technicians – Technology Developments	32	32	29	29	31	31	32	33
	Technicians – IT services	9	9	9	9	9	9	9	9
	Technicians - others	16	18	18	18	18	18	18	18
Administration	Administrative– IAC staff	45	45	45	44	45	46	47	48
	Apprenticeship contracts	8	8	8	10	10	10	10	10
	TOTAL	403	417	432	440	458	465	473	480

Researchers: We expect to reach the number of 44 IAC permanent employed researchers, by the end of this new period of four years. This means a net increase of 12 researchers over the period out of which 7 are "Científicos Titulares de OPIs" and 5 are new "Técnicos Superiores Especializados de OPIs"

PhD students: Under the framework of this new multi-year plan, we do not intend to increase/decrease the number of PhD students.

Technical staff: Around 3 new permanent positions/year (engineers or technicians) are needed during the new four-year period, to face the new challenging projects, as well as to strengthen our technical capabilities. In addition we will increase another 3 temporary engineering positions/year.

Administrative staff: As part of our objectives to reach a more balanced distribution of the IAC staff, and to strengthen our administrative units in support of the new large initiatives for the coming years, we propose to generate 1 new positions/year during this programme. Action 35.

Apart from our aforementioned estimates concerning new permanent positions at the IAC (researchers, technical and administrative staff), we have estimated also the evolution of our staff under temporary contracts. In this regard the recruitment of engineers associated to our participation in the Large Institutional Projects, is of special relevance. Funds to cover these engineering temporary contracts will come mainly from the "Agustín de Betancourt" Programme (Cabildo de Tenerife), and from other competitive funding schemes (EC funds, international collaborations, etc).

3.4.2. Budgetary Plan

The following Budgetary Plan indicates the funding baseline (internal and external) to support our Strategic Plan. By "Internal Funding" we refer to the annual budget contributions made by the Spanish State and by the Regional Government. "External Funding" refers to the funds obtained from national and international competitive programmes, to funds associated to the International Agreements of the *OOCC* and to the additional funding required to ensure our participation in the **Large Institutional Projects** (EST, CTA, NRT, TMT, IACTEC, etc). It is assumed that these projects can be undertaken only if decisions by funding agencies, i.e. beyond the IAC capacity are taken, and other additional funds are made available. Financial estimates for these large projects are described in 3.4.4.

Funding programmes

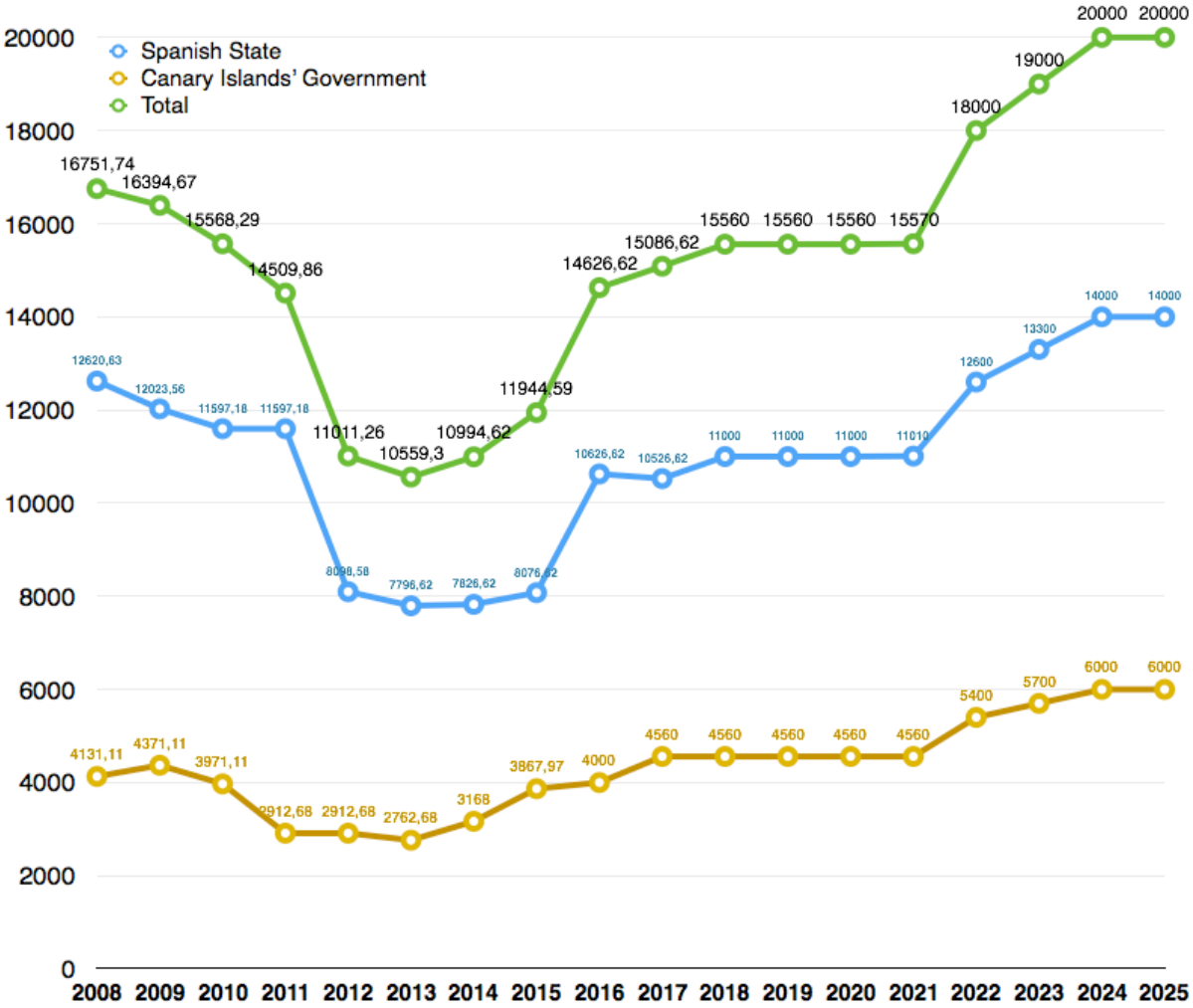
The external funding to cover additional personnel and operative costs is ensured through competitive programmes at all levels and through other special programmes that the IAC has access to (e.g. RIS3). In this sense, the IAC is actively participating in different public funding programmes to obtain the needed resources. It is also foreseen to implement a strategy to obtain financial support from private bodies.

Concerning Public Programmes supporting RTD activities, the most relevant ones are:

- Spanish Science, Technology and Innovation Strategy (EECTI)
- Horizon Europe 2021 - 2027
- New Canary Islands' RIS3. 2021 – 2027.
- State Recovery and Resilience Funds 2021 - 2022
- Other specific European funds like the European Regional Development Funds (ERDF) 2021-2027.

Overview of these funding programmes, and especially how the activity of the IAC fits into them, are briefly outlined below.

BUDGETARY PLAN (Keuros)
Consortium members contributions (2008- 2025)



Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Spanish State	12620,63	12023,56	11597,18	11597,18	8098,58	7796,62	7826,62	8076,62	10626,62
Canary Islands' Government	4131,11	4371,11	3971,11	2912,68	2912,68	2762,68	3168,00	3867,97	4000,00
Total Incomes	**16.751,74**	**16.394,67**	**15.568,29**	**14.509,86**	**11.011,26**	**10559,30**	**10994,62**	**11944,59**	**14626,62**

Year	2017	2018	2019	2020	2021
Spanish State	10.526,62	11.000,00	11.000,00	11.000,00	11.010,00
Canary Islands' Government	4.560,00	4.560,00	4.560,00	4.560,00	4.560,00
Total Incomes	15.086,62	15.560,00	15.560,00	15.560,00	15.570,00

PROPOSED BUDGETARY PLAN 2022 -2025 (Keuros)

Year	2022	2023	2024	2025
Spanish State	12.600	13.300	14.000	14.000
Canary Islands' Government	5.400	5.700	6.000	6.000
Total Incomes	**18.000**	**19.000**	**20.000**	**20.000**

DISTRIBUTION OF THE BUDGETARY PLAN 2022 -2025

Expenditure (Keuros)	2022	2023	2024	2025
Personnel	11.500	11.600	12.100	12.100
Operations	4.100	4.600	5.000	5.000
Investments	1.600	2.000	2.100	2.100
Transfers (ING and CTA)	800	800	800	800
Total Expenditure	18.000	19.000	20.000	20.000

Figure 3.3

Budget evolution (k€) (internal plus external funding 2020– 2025)

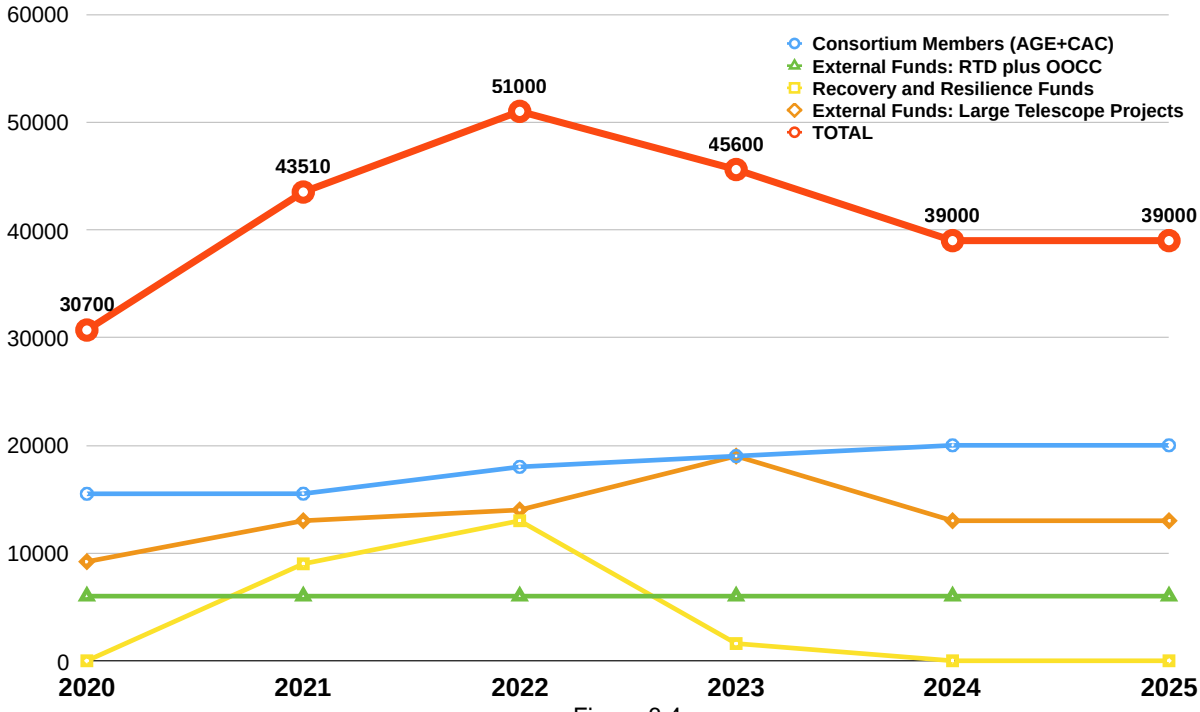


Figure 3.4

Current Science, Technology and Innovation Strategy (EECTI)

The Spanish Science, Technology and Innovation 2021-2027 Strategy (EECTI 2021-2027) is the basic instrument for consolidating and strengthening the Science, Technology and Innovation System over the next seven years.

The ECCTI 2021-27 is considered to facilitate the articulation of Spanish RDI policy with the policies of the European Union, in order to make the best use of the synergies between the different programmes. Following the principles of the EECTI, the new Scientific, Technical and Innovation Research Plan (PEICTI 2021-2027) is under construction., which means that the plan for the past period 2017-2020 is currently effective.

Under this framework, there are several multiannual sub-programmes in which the IAC has clear options to succeed as specified by the following considerations:

- **Sub-programmes on Talent Development and Employability (Training, Recruitment and Mobility)**: the proven track record of the IAC in training (thesis supervision, organization of international schools, seminars, master practices, agreements with other research centres and companies, etc.) and its technical and human resources provide a unique opportunity to researchers and engineers in their training phase. This privileged position serves as a benchmark of high scientific and technical level for the implementation of grants, actions and contracts provided by this Programme. Moreover, the IAC has a strong structure to support and qualify all the researchers and technologists who join projects run by this centre. The actions envisaged under the State Subprogram for the recruitment of young talents correspond well to IAC's wide experience, especially in recruiting doctors, technologists and managers. Finally, the IAC has a long tradition in international collaborations with the consequent mobility of our staff to ensure the maximum benefit from these transnational relations, as well as receiving numerous national and foreign researchers in our headquarters and observatories.

- **State Subprogram for Knowledge Generation:** The IAC has been actively involved in the implementation of fundamental research projects in the field of astrophysics, with more than a hundred projects approved in the national plans and access to other sources of regional and European funding, increasing substantially its number of awarded projects. The experience gained over the last decade has enabled many research groups at the IAC, now well positioned in large international consortiums as well as in leading emerging lines of research in collaboration with other outstanding international centres. Thus, the type of actions and projects considered under this subprogram are perfectly integrated with the IAC's strategy for development of astrophysics and related technologies in Spain.

- **State Subprogram for the Development of Emerging Technologies**: In this regard, we have already mentioned IACTEC, a technology centre for the development of advanced scientific instrumentation for astrophysics, space, and related areas (Earth observation, medicine, etc.). The expertise accumulated in leading technologies, thanks to our participation in projects such as GTC, and a variety of instruments for use in space, puts the IAC in a good position to prioritize the development of emerging technologies that may generate new products with high added value.

- **State Subprogram for Capacity Building:** The IAC is one of the centres designated 'Severo Ochoa Centre of Excellence' by the Spanish government, representing a world leading institution and a clear example of the quality and relevance of the pioneering scientific research carried out in Spain. This accreditation allows the IAC to continue with the implementation of a prominent Research Program and an internationally competitive

Human Resource Program started in 2012, and which covers the period 2020-2023. The extension of this award is the confirmation of the high capability of the IAC as a Centre of Excellence in the field of astrophysics.

- **State Subprogram for Research Infrastructures:** The *OOCC* are effective catalysts that contribute to the development of astrophysics and its related technologies in Spain. The strategic plan approved by the IAC to maintain the international leadership of its Observatories is well aligned with the national priorities laid down by the Ministry of Science and Innovation. Among other activities the IAC is taking advantage of promoting actions for its participation in international organizations such as ESO, and for the construction and operation of major research infrastructures (EST,NRT, CTA and possibly TMT), which are clear targets to be hosted in our observatories.

Horizon Europe

At European level Horizon Europe is the biggest EU Research and Innovation programme ever with a funding of nearly €95,5 billion over 7 years (2021 to 2027) – in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market. The IAC has significant experience in obtaining external funding from the previous European Framework Programmes for RTD actions. As an example, it is noteworthy that we currently coordinate the Preparatory Phase of the European Solar Telescope (PRE-EST, 9 million euros, 23 partners from 17 countries), as well as the already finished Integrated Infrastructure Initiative (I3) on solar physics (SOLARNET, 6 million euros, 32 partners from 15 countries). We also obtained 4 ERC Grants, host many Marie Curie Researchers (5 at the moment) and participated in 10 Initial Training Networks coordinating two of them (DAGAL, 2 million euros, 6 partners and SOLAIRE, 3 million euros, 13 partners).

This new Horizon Europe programme is an excellent opportunity to obtain the additional resources needed to carry out some of the new activities foreseen by this Strategic Plan, serving as booster to the internationalisation strategy of the Observatorios de Canarias and strengthening IAC position as international centre of excellence.

Pilar I. Excellent Science.
The ERC's mission is to encourage the highest quality research in Europe through competitive funding and to support investigator-driven frontier research across all fields, including Science of the Universe. To attract young prominent researchers to the IAC is one of its research strategies required merely to consolidate the Institute as a more effective global player. Thanks to a enhanced support to potential applicants, the IAC has obtained an improved success ratio in H2020 in this key financial instrument, broadening our chance of bringing about new and even unpredictable scientific discoveries in astronomy and astrophysics.

For the advanced training and international mobility of its research staff, the IAC has an ally in the Marie Skłodowska-Curie (MSC) actions, which support the career development and training of researchers in all scientific disciplines through worldwide and cross-sector mobility at all stages of their careers. The IAC is actively working to maintain its main achievements in this programme, by focussing its core efforts on Innovative Training Networks and Individual Fellowships. Aligned with the search of excellence on human resources management and the improvement of researchers careers, the IAC has been awarded with the "Human Resources Strategy for Researchers" Award (HRS4R).

Research Infrastructures are considered one of the main success of the ERA and the IAC has contributed to that developing a wide experience under the Research Infrastructure Program through the different EU Framework Programs.

Thanks to its privileged position hosting the biggest collection of Research Infrastructures in astronomy in Europe, the IAC has made remarkable progress in recent years with a significant success ratio in those calls for projects providing funds for integrating current facilities by way of transnational access, joint research activities and networking activities as well as for design studies and support for preparatory phase projects. The IAC has special interest to host major European RIs at the *OOCC*.

The IAC supports ESFRI recommendations made on the report *Supporting the Transformative Impact of Research Infrastructures on European Research*. This report affirms that to maintain and strengthen Europe's leading position on Research Infrastructures, the constant development of research, scientific and innovation skills, state-of-the-art facilities and related activities is crucial. In line with this, the IAC expects to profit the opportunities to be opened under the future INFRADEV and INFRAIA calls at Horizon Europe, but as well from actions that will promote the transit from current infrastructures readiness levels to higher ones (from RL2-RL3 to RL4 and RL5) that will leverage the operation of the mentioned RIs led by the IAC CTA, EST and NRT.

Pilar II. 'Global Challenges and European Industrial Competitiveness
IAC is also strongly involved in Horizon Europe pillar 2, that supports research into societal challenges, reinforcing technological and industrial capacities, in particular the 'Digital, Industry and Space' Cluster through partnerships with other Member States' stakeholders working jointly on research and innovation, transferring astronomy knowledge to Society and collaborating with space missions for the integration of astrophysical data.

The missions included in the Horizon Europe Program provide an attractive opportunity for IAC to contribute to these initiatives through IACTEC, whose activities are aligned with some of these missions proposed by the European Commission.

Pilar III. Innovative Europe

Thanks to its international and technological character of some of the IAC projects, the European industry is involved in its activity. Ideas behind the open innovation concept and culture are being applied and are broadly inherent to the development of the telescopes instrumentation, systems and subsystems. Thus, the IAC technological projects provide an excellent opportunity to develop new applications during the development of breakthrough technologies, increasing the capabilities of the industrial sector and strengthening the cooperation between academia and industry.

This fact, together with the technological and innovation hub IACTEC, provides the IAC a privileged position to benefit from the opportunities to be opened under the new European Innovation Council and the existing and forthcoming Knowledge Innovation Communities (KICs) under the European Institute of Innovation& Technology.

Widening and Spreading Excellence under Horizon Europe
The Canary Islands' outermost region has an economy overwhelmingly based on tourism and services, with secondary contributions from agriculture. There is no significant industry to speak of, and very little RTD outside of a few localized research institutions such as IAC and individual departments at the two regional universities, Las Palmas de Gran Canaria (ULPGC) and La Laguna (ULL).

As mentioned before, the IAC was one of the first "Severo Ochoa Centres of Excellence" recognized by the National Government and it has maintained this recognition for more than a decade. It is the only centre of excellence in the region.

With the new opportunities arising under the **Widening actions in Horizon Europe**, IAC is well aligned to consolidate and expand even further this leadership position. Being a widening actor will provide IAC a unique opportunity to increase the number of participations and success rates in research and innovation projects in other parts of Horizon Europe and reinforce its collaborations with industry to foster brain circulation and inter-sectoral mobility for researchers and innovators.

IAC is building the necessary capacity to allow its successful participation in the R&I process at the international level, increasing networking and excellence. By participating in some of the main widening actions (ERA Charis, Teaming and Twinning), IAC expects to advance to the competitive edge at European and international level.

Finally, there are other funding opportunities available to IAC's research staff, which will be mapped and followed closely in order to maximize the European routes available for period 2021-2027 to strengthen our research strategy.

Recovery and Resiliance Facility.

The Recovery and Resilience Facility consists of large scale financial support to both public investments and reforms, notably in green and digital, which make EU countries' economies more resilient and better prepared for the future.

The Spanish Recovery, Transformation and Resilience Plan is a national project defining the roadmap for the modernisation of the Spanish economy, for the recovery of economic growth and job creation, for a robust, inclusive and resilient economic rebuilding after the Covid-19 crisis, and to respond to the challenges of the coming decade. In particular, it is planned an institutional reform and strengthening of the capacities of the national system of science, technology and innovation, to accompany and nourish a sustainable increase in public and private investment in R&D, via:

- ✓ the improvement of R&D&I project calls,
- ✓ human resources and scientific and technical equipment;
- ✓ the renovation of large national research infrastructures and the participation in international infrastructure;
- ✓ reinforcing the regular financing for the CDTI's projects and evaluation capabilities;
- ✓ the creation of new centres of excellence;
- ✓ the design of new innovation tools and instruments;
- ✓ and the digitisation of the management of R&D&I.

Additionally, specific plans will be drafted to drive science and innovation in key priority areas: the green transition, biomedicine and potentiation of innovation and research in health and vaccines, the aeronautical industry, and advanced computation technologies.

The IAC's Investment and Reform Plan for economic recovery includes two major actions. The first, "Cutting-edge technologies for astrophysical instrumentation", with a budget of 2 million euros for 2021 (3.5 M€ for 2022). It aims to improve and increase the IAC's capabilities in advanced technologies for systems: mechanical and opto-mechanical, cryogenic and vacuum systems, precision mechanics, adaptive optics systems, fiber optics, control systems, sensor characterization, electronic systems and software design.

The second major action to be financed by the State under the Recovery, Transformation and Resilience Plan aims to make IACTEC a centre of international reference for advanced technologies in Space, Optics and Biomedicine, with a budget of 7 million euros by 2021 (9.5 million euros by 2022). The objective is to position IACTEC at the forefront for advanced optical systems; to promote collaboration with the science industry, the promotion of innovation and the diversification of the economy; contribute to the development of talent and a dynamic and innovative productive fabric, in the Canary Islands and the rest of Spain, by promoting the co-production of technological knowledge with technology-based companies, especially in the Astrophysics and Space sector, prioritized by the RIS3 strategy of the Canary Islands, and thus fostering the emergence of new business activities with high added value in the region.

In this environment of innovation, the IAC will foster its strategic capabilities, such as optics, electronics, the development of specific software applications and precision mechanics. IACTEC will focus its activity on the application of advanced optical technologies for space sciences and scientific instrumentation in sectors such as medicine, security and the environment. It will also develop transferable R&D projects, mainly in the field of technologies for capturing and processing light and electromagnetic waves in general.

It will also enable technological and business cooperation to take advantage of the IAC's knowledge in the development of advanced scientific instrumentation, while contributing to

industrial development and the commercialization of high value-added products in the Canary Islands.

New Canary Islands' RIS3. 2021 – 2027.

Apart from the H2020 Framework Programme, the EC and the Member States/Regions have been actively working on the definition of the so-called 'National/Regional Research and Innovation Strategies for Smart Specialisation' (RIS3 strategies).[3] The EC request national and regional authorities across Europe to draw up their strategies, so that the EU's Structural Funds can be used more efficiently and synergies between different EU, national and regional policies, as well as public and private investment, can be increased. The design and implementation of these strategies is a pre-condition for using the European Regional Development Funds (ERDF) to support RTD investments in that region/country. These strategies have to be ready along 2021.

The IAC has been participating in several meetings and consultations organized by our regional authorities to contribute to the definition of priorities and instruments for the RIS3 in the Canary Islands. According to the preliminary version of this strategy there will be a specific priority for Socio-economic valuation of RTD including specialization and strengthening of astrophysics and space, maritime sciences, biotechnology and biomedicine.

Astrophysics is explicitly have been included since 2014 as one of the main strengths of these islands to which support and resources will be assigned. Concerning 'smart leadership in tourism', our region will focus, among other specific actions, on improving the competitiveness of this important economic sector by diversifying its tourist products. Astronomical tourism is one of the products mentioned in the document as being a fundamental, but hitherto insufficiently explored, complementary product to generate economic value for our region. Our research activities and first-class infrastructures at the observatories are considered as a valuable resource for touristic products.

However, it is under the heading of priority on socio-economic valuation of RTD activities that astrophysics, and consequently the activity of the IAC, acquires a clear prominence. It is mentioned as the first and most consolidated RTD activity deserving special support by RIS3. Apart from a very detailed overview of the overall strategy to be followed for this priority, a set of actions is described that need to be implemented, especially regarding IAC activity. The RIS3 will contribute, among other things, towards:

- Attracting the best research infrastructures, such as NRT, TMT, EST and CTA, and other similar telescope facilities.
- Supporting research excellence, as well as the development of products of economic value for the regional economy (such as astronomical tourism).
- Supporting technology transfer to the socio-economic sector with initiatives such as IACTEC.
- Internationalization of our research and technological activity.
- Training of highly specialized researchers and engineers, especially in the field of advanced instrumentation for astrophysics and related fields.

[3] More info on RIS3 Strategies at: http://ec.europa.eu/regional_policy/sources/docgener/informat/2014/smart_specialisation_en.pdf

3.4.3. New infrastructures: IACTEC and CATELP

Apart from ordinary maintenance, improvements and civil works in our facilities at the IAC's HQs, and at the Observatories, there are two new major buildings that will be developed in the four coming years:

- The Center for Astrophysics and Technology of La Palma (CATELP). This is a joint initiative of the Cabildo of La Palma and the IAC, which will be constructed at sea-level. The current facilities of the IAC CALP will be transferred to this new location. This initiative is still in process of formalization, the design of the building is finished but funding is awaiting decisions at Cabildo. The expected duration of the construction phase is 3 years.
- The IACTEC centre is already built by Cabildo of Tenerife and entered operation in year 2021. An agreement for operations has been signed where Cabildo contributes 150 K€/yr to the operation costs and supports a "Technology Capacitation" programme at IAC for 850 K€/yr. The IAC covers the remaining costs of operations and the costs of equipping the laboratories for Advanced Optical Systems, Space technologies and Technologies for Biomedicine.

3.4.4. Large Institutional Projects

The projects listed in the table below are considered **Large Institutional Projects** (LIP) at the IAC. They are briefly described in the accompanying annexes. We give here the amount of funding needed at the IAC for the implementation of these projects. These financial figures are in addition to the baseline IAC budget described above and are shown separately because of their strong external dependency.

Project	2022	2023	2024	2025	Total
Cherenkov Telescope Array (CTA-North)	10,000	10,000	10,000	.....	30,000
European Solar Telescope	2,000	2,000	6,000	10,000	20,000
New Robotic Telescope	1,000	1,000	2,000	2,000	6,000
IACTEC	11,000	1,000	1,000	1,000	14,000
TMT	.....	1,000	1,000	1,000	3,000
Total	24,000	15,000	20,000	14,000	73,000

Additional funds above IAC baseline budget to undertake Large Institutional Projects at the IAC during the period 2021 – 2025. Amounts in k€.

A significant fraction (70%) of the total 73 M€ needed to carry out these Large projects during period 2022-2025 has already been awarded to IAC:

CTA: funding of 30 M€ was approved by the Ministry of Science and Innovation.
The EST has received a 4M€ grant from the EU and another 5 M€ grant from the Regional Government (FEDER) for the period 2020-2022.
The New Robotic Telescope project was awarded 2 M€ by the Regional Government (FEDER) for period 2020-22.
IACTEC is funded by by the Plan for Recovery of MICINN which will provide approx. 7 M€ in 2021 and 10 M€ during 2022 for laboratory equipment and by Cabildo de Tenerife which contributes 1M€/year (850k€ Capacitación Tecnológica + 150k€ IACTEC running expenses).

2. *ACRONYM LIST*

AGE	Administración General del Estado
ALMA	Atacama Large Millimeter Array
AMS	Alpha Magnetic Spectrometer
ARENA	Antarctic Research, a European Network for Astrophysics
AOLI	Adaptive Optics Lucky Imager
ASK	Sounding Stars with Kepler
ASTRONET	European Astronomical Coordination Network
ATST	Advanced Technology Solar Telescope
AURA	Association of Universities for Research in Astronomy
AWS	Automatic Weather Station
CAC	Canary Islands' Regional Government
CARMENES	Calar Alto high-Resolution search for M dwarfs with Exoearths with Near-infrared and optical Échelle Spectrographs
CB	Consortium Board
CCOO	Observatorios de Canarias – Canary Islands Observatories
CDTI	Centro para el Desarrollo Tecnológico Industrial
CIMNE	Centro Internacional de Métodos Numéricos en Ingeniería
CMB	Cosmic Microwave Background
COROT	Convection, Rotation & planetary Transits
CSIC	Spanish National Research Council
CTA	Cherenkov Telescope Array
DAGAL	Detailed Anatomy of GALaxies
DIMMA	Automatic DIMM
EAST	European Association for Solar Telescopes
EC	European Commission
EDiFISE	Equalized and Diffraction-limited Field Spectrograph Experiment
E-ELT	European Extremely Large Telescope
EMIR	Espectrógrafo Multiobjeto InfraRojo
ERC	European Research Council
ERDF	European Regional Development Funds
ERP	Enterprise Resource Planning
ESA	European Space Agency
ESFRI	European Strategy Forum on Research Infrastructures
ESO	European Southern Observatory
ESPRESSO	Echelle SPectrograph for Rocky Exoplanet and Stable Spectroscopic Observations
EST	European Solar Telescope
EU	European Union
EUCLID	ESA mission to map the geometry of the dark Universe
FET	Future and emerging technologies
FRIDA	inFRared Imager and Dissector for Adaptive optics
FTE	Full Time Equivalent
GLORIA	GLObal Robotic-telescopes Intelligent Array
GTC	Gran Telescopio CANARIAS
GTCAO	Adaptive Optics Gran Telescopio CANARIAS
HELAS	European Helio and Asterosismology Network
HIRES	High Resolution Echelle Spectrometer
HORUS	High Optical Resolution Ultra-stable Spectrograph
I3	Integrated Infrastructure Initiative
IAC	Instituto de Astrofísica de Canarias
IACTEC	Technology Centre linked to the IAC
IAP	Institute for Astrophysics Potsdam
ICTS	Instalaciones Científico Técnicas Singulares
IMAX	Imaging Magnetograph eXperiment
INAF	National Institute of Astrophysics
ING	Isaac Newton Group
IPHAS	INT Photometric Hα Survey of the Northern Galactic Plane
IRAM	Institut de Radioastronomie Millimetrique
IRCAM	Infrared Camera
ISO	Infrared Space Observatory
ISS	Interlock and Safety System
ITP	International Time Programme
JEM-EUSO	Japanese Experiment Module (JEM) Extreme Universe Space Observatory
LIP	Large Institutional Projects

LISA	Laboratory of Imaging and Sensors for Astronomy
NRT	Liverpool Telescope 2
MACHOS	Massive astrophysical compact halo object
MAGIC	Major Atmospheric Gamma-ray Imaging Cherenkov Telescopes
MMT	Multiple Mirror Telescope
MPE	Max Planck Institute for Extraterrestrial Physics
MPIA	Max Planck Institute for Astronomy
MS-DESI	Medium Scale Dark Energy Spectroscopic Instrument
NISP	Near Infrared Spectrometer and Photometer
NJIT	New Jersey Institute of Technology
OGS	Optical Ground Station
OOCC	Observatorios de Canarias
OPI	Public Research Organization
OPTICON	Optical and Infrared Coordination Network
ORM	Observatorio del Roque de los Muchachos
OSIRIS	Optical System for Imaging and low/intermediate Resolution Integrated Spectroscopy
OT	Observatorio del Teide
OTRI	Oficina de Proyectos Institucionales y Transferencia de Resultados de Investigación
PCTT	Polo Científico y Tecnológico de Tenerife
PLATO	PLAnetary Transits and Oscillations of stars
PWV	Precipitable Water Vapour
QUIJOTE	Q-U-I JOint TEnerife
RB	Research Board
RIFI	Research Infrastructures Forsight Impact
RIS3	Research and Innovation Strategic for Smart Specialization
RoPACS	Rocky Planets Around Cool Stars
RTD	Research and Technology Development
SDSS	Sloan Digital Sky Survey
SIC	Servicios Informáticos Comunes
SIE	Servicios Informáticos Especificos
SLOAN	Sloan Digital Sky Survey
SOHO	Solar and Heliospheric Observatory
SOLARNET	High-Resolution Solar Physics Network
SOPHI	Solar Orbiter Polarimetric and Helioseismic Imager
SPIA	Solar Partially Ionized Atmosphere
SSC	Site Selection Committee
STScI	Space Telescope Science Institute
SWOT	Strengths, Weaknesses, Opportunities and Threats
UC3	Unidad de Comunicación y Cultura Científica
ULL	University of La Laguna
VISTA	Visible and Infrared Survey Telescope for Astronomy
VLT	Very Large Telescope
WEAVE	Wide-Field Multi-Object Spectrograph
WHT	William Herschel Telescope